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VOLUME XX, 1927

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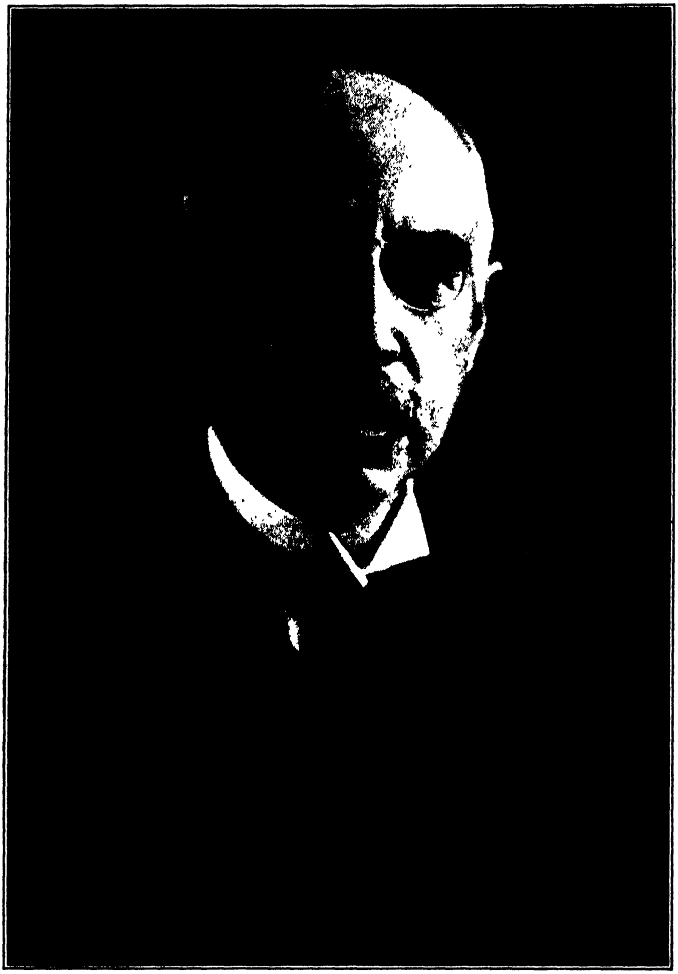

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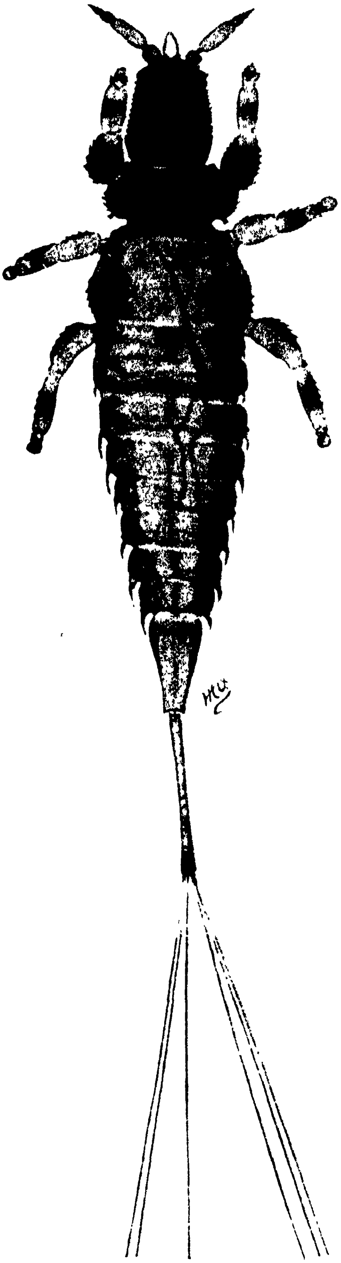

Stephanothrips occidentalis H. & W.

(The colors are of the species when seen by transmitted light. By reflected light the sub-hypodermal pigmentation is maroon red as stated in description.)

ANNALS
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Volume XX . MARCH, 1927 Number 1

A SYNOPSIS OF THE THYSANOPTEROUS FAMILY UROTHRIPIDÆ.

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University of Rochester,
and
C. B. WILLIAMS,
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The primary purpose of this paper is to describe more fully than was then possible, and to illustrate, the two new Urothripidæ made known in a preliminary way by the authors in Psyche, Vol. XXXII, 1925, pp. 68 and 69. At the same time it has been found convenient to include brief keys to the known genera and species of the family.

The Urothripidæ are one of the most specialized and aberrant families of the Thysanoptera, and for these reasons a group of more than usual interest to the student. Their pale coloration and lack of wings gives them a larviform appearance; and their great rarity in collections is possibly due more to their having been overlooked or neglected by collectors and to the obscure situations in which they live than to an actual scarity in nature. However that may be, only twenty-eight adult specimens have been recorded in the literature; and these have more frequently been taken under dead leaves than in any other habitat.

Historically our knowledge of the group is recent. The first representatives of the family, two species belonging to different genera, were described by Buffa in January, 1909, from specimens taken in Italy. Later in the same year Bagnall based a third genus and species on two specimens from German

East Africa, and erected for the group the new family Urothripidæ. Mr. Bagnall's study of the two specimens known to him led him to ascribe to the group eleven spiracular openings instead of the typical number, four, found throughout the order; and three years later this character was used by him as the principal reason for the elevation of the Urothripidæ to subordinal rank, the name Polystigmata being given them in reference to the supposed supernumerary spiracles. Later in the year, Trybom, at the time of his description of still another genus and two new species, both from Natal, stated that the so-called stigmata observed by Bagnall were equally visible from both the dorsal and ventral surfaces and in his opinion not true stigmata at all. Concurring in Trybom's opinion, Hood, in 1915, placed the Suborder Polystigmata as a synonym of the Suborder Tubulifera and divided the latter into two new superfamilies, the Phlœothripoidea and the Urothripoidea. Since that date nothing of importance concerning the group was brought to the fore until the present authors, in April, 1925, extended the known geographical range of the group by describing from the New World a new genus and two new species taken nearly ten years previously by Mr. Williams in the West Indies and South America. The number of known genera is thus five, and the number of species seven, distributed in the Palæarctic, Ethopian, and Neotropical regions; but of course many more species await discovery.

Superfamily UROTHRIPOIDEA Hood.

1912. (April 13) ["A new suborder"] Hood, Proc. Biol. Soc. Washington, Vol. XXV, p. 64

1912. (August). [Suborder] *Polystigmata* Bagnall, Ann. Mag. Nat. Hist., Ser. 8, Vol. X, p. 220.

1915. *Urothripoidea* Hood, Proc. Biol. Soc. Wash., Vol. XXVIII, p. 59.

Body decidedly roughened above; all known species wingless. [Maxillary palpi *two*-segmented, but basal segment very short]. Antennæ four- to seven-segmented. Hind coxæ more widely separated than fore and middle pairs. Female without ovipositor, the terminal segment of both sexes continuous beneath and tubular; ninth abdominal segment longer than eighth; terminal abdominal hairs very much longer than tube.

Embraces the following family, only.

Family UROTHRIPIDÆ Bagnall.

1909. *Urothripidæ* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 126.
1910. *Urothripidæ* Bagnall, Fauna Hawaiiensis, Vol. III, Pt. VI, p. 677.
1911. *Urothripidæ* Bagnall, Ier Cong. Int. d'Ent., p. 283.
1912. *Urothripidæ* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 31.
1915. *Urothripidæ* Hood, Proc. Biol. Soc. Wash., Vol. XXVIII, pp. 54, 59.

Five genera and seven species, all recent, known from the Palæarctic, Ethiopian, and Neotropical faunal realms.

Key to Genera.

I. Antennæ 7-segmented.
  a. Vertex of head without prominent bristles; antennal segments 3–5 about as wide as long; tube much shorter than head, relatively stout, three to five times as long as greatest width, with six long hairs at tip. **Urothrips** Bagnall.
  aa. Vertex of head with a pair of prominent, anteriorly-directed bristles; antennal segments 3–5 decidedly longer than wide; tube much longer than head, very slender, fully ten times as long as greatest width, with four long hairs at tip.......... **Bradythrips** Hood and Williams.
II. Antennæ either 4- or 5-segmented.
  b. Antennæ 5-segmented.
    c. Vertex of head without prominent bristles; antennal segments 4 and 5 not closely united, 5 pedicellate; ninth abdominal segment less than twice as long as 8; tube with four long hairs at tip.............................. **Bebelothrips** Buffa.
    cc. Vertex of head with 4 to 6 prominent bristles; antennal segments 4 and 5 broadly joined; ninth abdominal segment at least twice as long as 8; tube with six long hairs at tip. **Stephanothrips** Trybom.
  bb. Antennæ 4-segmented; tube with four long hairs at tip. **Amphibolothrips** Buffa.

Genus **Urothrips** Bagnall.

1909. *Urothrips* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 126.
1911. *Urothrips* Bagnall, Ier Congr. Int. d'Ent., pp. 283–288.

Two species, both Ethiopian.

Key to Species.

a. Segment 7 of antennæ subequal in length to 6; tube about four-fifths the length of head. (German East Africa; Natal)..... **U. paradoxus** Bagnall.
aa. Segment 7 of antennæ nearly twice as long as 6; tube not more than two-thirds the length of head. (Natal).................. **U. bagnalli** Trybom.

Urothrips paradoxus Bagnall.

1909. *Urothrips paradoxus* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 127, Tab. III, Figs. 1–13.
1911. *Urothrips paradoxus* Bagnall, Ier Congr. Int. d'Ent., pp. 283–288.
1912. *Urothrips paradoxus* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 32.

Originally described from one male and one female taken in German East Africa, without data on habitat. Trybom had one female, taken under fallen leaves, Natal, January 31, 1905.

Urothrips bagnalli Trybom.

1912. *Urothrips bagnalli* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 33, Taf. 4, Figs. 33–44.

Known only from 4 ♂♂, 3 ♀♀, 1 prepupa, and 4 nymphs, taken under fallen leaves, Nàtal, January 31 and July 6, 1905.

Genus **Bradythrips** Hood and Williams.

1925. *Bradythrips* Hood and Williams, Psyche, Vol. XXXII, p. 68.

Only the following species is known. Neotropical.

Bradythrips hesperus Hood and Williams.

(Pl. II, Figs. 1 and 2).

1925. *Bradythrips hesperus* Hood and Williams, Psyche, Vol. XXXII, p. 68.

Female (apterous).—Length about 1.8 mm. Color straw yellow, with dorsum and front of head, pterothorax, and middle legs, brown; abdomen narrowly brown at sides of segments 2–9; hind legs with coxæ and middle of tibiæ brownish; tube dark brown at extreme tip; all tarsi with cup brown; antennæ nearly colorless, segment 7 often lightly grayish; subhypodermal pigmentation bright crimson-red, some in the darkened portion of head, none in prothorax, densest along sides of pterothorax, and continued into abdomen in two narrow streaks, one along either side of segments 1–8.

Head about 1.5 times as long as wide, broadest at about one-fourth from base, converging regularly to eyes and slightly toward base; occiput somewhat elevated; dorsal and lateral surfaces strongly roughened with tubercles which are largest on occiput, some of them bearing short, stout, dilated bristles; ventral surface smooth; vertex rounded in front of eyes, but scarcely overhanging insertion of antennæ, set with one pair of stout, pale brown bristles which are slightly expanded at tip and which arise from strong tubercles; postocular bristles wanting. Eyes minute, consisting of about three facets. Ocelli absent. Antennæ 1.2 times as long as head, seven-segmented (see Pl. II, Fig. 1, for form of segments); sense cones apparently absent.

Prothorax about one-half as long as head and (inclusive of coxæ) about twice as wide as median length of pronotum, surface without tubercles or sculpture of any kind and apparently lacking all bristles excepting a short, colorless pair, which are slightly dilated apically, at posterior angles. Pterothorax nearly twice as long and fully 1.5 times as wide as prothorax, trapezoidal, the sides widely diverging, its entire dorsal and lateral surfaces roughened with small tubercles interspersed with larger, spiniferous ones similar to those on head. Legs moderately stout; tarsi without claws.

Abdomen broadest at second segment and tapering evenly to base of tube; surface nearly smooth; each tergite with two transverse rows of short, dilated, colorless bristles; posterior angles of intermediate segments slightly produced and bearing a short, dilated bristle which is parallel to the axis of the body; ninth abdominal segment about 2.8 times as long as eighth, surface nearly smooth. Tube about 1.6 times as long as head and about 1.6 times as long as ninth abdominal segment, slightly narrowed at middle and distinctly widened at apex, which is in width about one-twelfth the total length. Terminal hairs four in number, simple in structure, about 2.75 times as long as tube and half the total body length.

Measurements of holotype (♀): Length 1.81 mm.; head, length 0.201 mm.; greatest width 0.135 mm., width across eyes 0.108 mm.; eyes, length 0.027 mm.; prothorax, length 0.096 mm., width (inclusive of coxæ) 0.195 mm.; pterothorax, length 0.186 mm., greatest width 0.309 mm.; interval between fore coxæ 0.135 mm., middle coxæ 0.144 mm., hind coxæ 0.156 mm.; abdomen, greatest width 0.270 mm.; segment 8, length 0.072 mm.; segment 9, length 0.204 mm.; segment 10, length 0.330 mm., width at base 0.030 mm., at middle 0.019 mm., at apex 0.027 mm.; terminal hairs, length 0.912 mm.

Antennal segments:	1	2	3	4	5	6	7
Length (μ)............	21	33	40	36	34	33	45
Width (μ)............	27	30	22	21	21	18	16

Total length of antenna 0.242 mm.

Male (apterous).—Length about 1.3 mm. Almost identical with female in color and structure, though smaller. Tarsi unarmed.

Measurements of allotype (♂): Length 1.28 mm.; head, length 0.168 mm., greatest width 0.117 mm., width across eyes 0.087 mm.; prothorax, length 0.081 mm., width (inclusive of coxæ) 0.165 mm.; pterothorax, length 0.144 mm., greatest width 0.225 mm.; interval between fore coxæ 0.090 mm., middle coxæ 0.099 mm., hind coxæ 0.102 mm.; abdomen, greatest width 0.195 mm.; segment 8, length 0.060 mm.; segment 9, length 0.120 mm.; segment 10, length 0.237 mm., width at base 0.018 mm., at middle 0.014 mm., at apex 0.021 mm.; terminal hairs, length 0.720 mm.

Antennal segments:	1	2	3	4	5	6	7
Length (μ)............	21	30	37	30	30	30	48
Width (μ)............	25	27	21	21	21	16	13

Total length of antenna 0.226 mm.

Described from three females and two males, taken "at base of *Imperata* grass," Issoro, N. W. D., British Guiana, July 26 and August 3 and 6, 1916, C. B. Williams [Nos. 841, 847, and 848].

Genus **Bebelothrips** Buffa.

1909. *Bebelothrips* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 195.

1909. *Bebelothrips* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 136.

One species. Palæarctic.

Bebelothrips latus Buffa.

1909. *Bebelothrips latus* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 196, Figs. 2 D, 3.

Three females were known to Buffa, taken in January, 1909, Isola del Giglio, Italy.

Genus **Stephanothrips** Trybom.

1912. *Stephanothrips* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 42.

Two species. Ethiopian and Neotropical.

Key to Species.

a. Vertex with **two** pairs of strong, anteriorly-directed bristles; tube about 1.1 times as long as head and 1.3 times as long as ninth abdominal segment. (Natal)..**S. buffai** Trybom.

aa. Vertex with **three** pairs of strong, anteriorly-directed bristles; tube nearly 1.5 times as long as head and about 1.8 times as long as ninth abdominal segment. (St. Croix and Trinidad, West Indies). **S. occidentalis** Hood and Williams.

Stephanothrips buffai Trybom.

1912. *Stephanothrips buffai* Trybom, Arkiv. f. Zool., Bd. 7, No. 33, p. 43, Taf. 5, Figs. 45–54.

Known from one male, one female, and one nymph taken under fallen leaves, Natal, January 31, 1905.

Stephanothrips occidentalis Hood and Williams.

(Pl. I; Pl. II, Figs. 3–5).

1925. *Stephanothrips occidentalis* Hood and Williams, Psyche, Vol. XXXII, p. 69.

Female (apterous).—Length about 1.4 mm. Color straw yellow with head, prothorax and fore femora, except apex, dark brown. Last two antennal segments dark brown, rest of antennæ light; fore tibiæ, mid and hind femora and tibiæ, darkened with brown at middle and along outer surface; tarsi with the usual darkened cup; lateral third or fourth of pterothorax and of abdominal segments 1–8, slightly darkened with brown, and with maroon-red subhypodermal pigmentation which continues in prothorax and head; median line of abdomen faintly indicated by a series of light grey blotches; ninth segment of abdomen narrowly darkened with brown along outer surface; tenth segment distinctly brightened with yellow, shading distally to dark brown at extreme apex.

Head about 1.13 times as long as wide, broadest at about one-fourth from base, converging regularly to eyes, and distinctly narrowed at base. Dorsal and lateral surfaces strongly roughened with tubercles which are largest and transversely elongated on occiput; ventral surface smooth; vertex broadly rounded and semi-circularly produced in front of eyes to overhang insertion of antennæ, and set along anterior margin with three pairs of blunt bristles which are slightly expanded at tip, the middle pair about three-fifths as long as third antennal segment and curved inwards so that the tips almost meet, the two outer pairs shorter and straight, equal in length, the outer pair set close to, and at a lower level than, the other; each of these bristles arises from a strong tubercle; postocular bristles wanting. Eyes minute, consisting of about three facets. Ocelli absent. Antennæ almost as long as head, five-segmented, inserted below vertex; segment 1 subquadrangular, not visible in dorsal view; segment 2 broadly globose and pedicellate; segment 3 three times as long as wide, narrowly pedicellate at base, and slightly narrower at apex than at middle; segment 4 slightly longer than wide, broadest at middle subquadrangular, not pedicellate; segment 5 sharply conical, about twice as long as basal width. No sense cones present.

Prothorax about half as long as head and (inclusive of coxæ) two and one-half times as wide as long, with a broad, shallow depression on each side of the median line, in which are arranged irregular, subconcentric, dark, linear thickenings, interspersed with a few minute tubercles; a pair of short, stout, apically-expanded bristles arising from distinct tubercles, one at each hind angle of the prothorax; all other bristles wanting. Pterothorax about 1.45 times as long as prothorax, broadened posteriorly, greatest width about twice its length. Legs somewhat short and stout and roughened with minute tubercles; fore tarsus with a distinct, downwardly-curved claw on outer surface near apex; hind tarsus with a claw similar, but curved inwards; no claw apparent on mid-tarsus.

Abdomen broadest at second segment and tapering evenly to base of tube; surface nearly smooth; posterior angles of each segment slightly produced and bearing a short, dilated bristle which is parallel to the axis of the body; ninth abdominal segment about 2.6 times as long as eighth, width at apex 0.45 of greatest width, which is about one-fifth from base, surface with a few scattered, spine-bearing tubercles. Tube nearly 1.5 times as long as head and about 1.8 times as long as ninth abdominal segment, slightly narrowed at middle and distinctly widened at apex, which is in width about one-ninth of the total length. Terminal hairs six in number, simple in structure, and about 2.5 times as long as the tube, only slightly less than half the total body length.

Measurements of holotype: Length 1.44 mm.; head, length 0.177 mm., greatest width 0.156 mm., width across eyes 0.126 mm.; eyes, length 0.030 mm.; prothorax, length 0.090 mm., width inclusive of coxæ 0.225 mm.; pterothorax, length 0.129 mm., width 0.264 mm.; distance between fore coxæ, 0.126 mm., mid-coxæ 0.111 mm., hind coxæ 0.141 mm.; abdomen, greatest width 0.261 mm.; segment 8, length 0.057 mm.; segment 9, length 0.147 mm.; tube, length 0.261 mm., width at base 0.022 mm., at middle 0.019 mm., at apex 0.028 mm.; terminal hairs, length 0.660 mm.

Antennal segments:	1	2	3	4	5
Length (μ)...........	24	30	81	21	30
Width (μ)...........	22	30	27	18	13

Total length of antenna, 0.18 mm.

Described from three females taken by miscellaneous beating, St. Croix, Dutch (now American) West Indies, March 10, 1915, C. B. Williams [No. 554]; and from one female "swept under cacao," Verdant Vale, Trinidad, British West Indies, May, 1915, F. W. Urich [C. B. W. No. 722].

Type locality: St. Croix.

This species differs from *Stephanothrips buffai* Trybom, the only other species in the genus, described from Natal, in several particulars. The most important of these are the possession of six, instead of four, bristles on the vertex, and the relatively much longer ninth and tenth abdominal segments. Both of these characters are perhaps of sufficient importance to warrant the erection of a new genus; but at the same time it is believed that no useful purpose would be served by such a course, with our present fragmentary knowledge of this family.

Genus **Amphibolothrips** Buffa.

1909. *Amphibolothrips* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 193.
1909. *Amphibolothrips* Bagnall, Ann. Mus. Nat. Hung., Vol. VII, p. 136.

One species. Palæarctic.

Amphibolothrips grassii Buffa.

1909. *Amphibolothrips Grassii* Buffa, Boll. Lab. Zool. R. Scuola Sup. Agr. Portici, Vol. III, p. 194, Figs. 1 and 2, A, B, C.

Known from four females taken in December among dead leaves, Lake of Albano, Italy.

EXPLANATION OF PLATES.

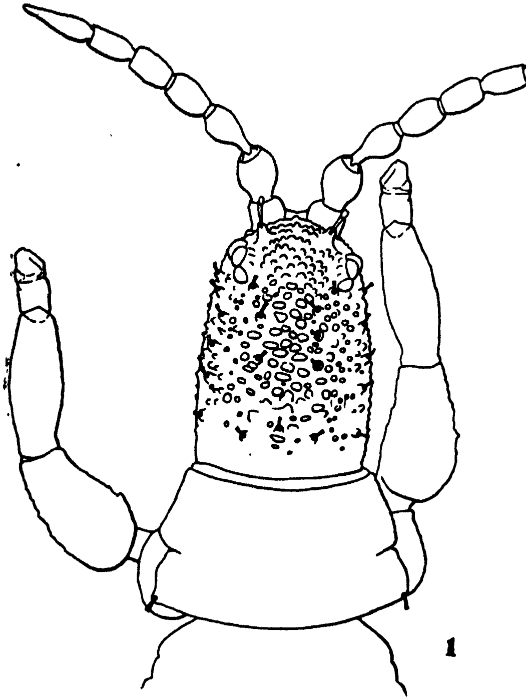
Plate I.

Stephanothrips occidentalis Hood and Williams, ♀, paratype.

Plate II.

(J. D. H. del., camera lucida).

Fig. 1. *Bradythrips hesperus* Hood and Williams. Head and prothorax, ♂, allotype. (Bristles on legs and antennæ omitted).
Fig. 2. *Bradythrips hesperus*. Tip of abdomen. ♀, paratype.
Fig. 3. *Stephanothrips occidentalis* Hood and Williams. Head and prothorax, ♀, holotype. (Bristles on legs and antennæ omitted).
Fig. 4. *Stephanothrips occidentalis*. Right fore tarsus, ♀, paratype.
Fig. 5. *Stephanothrips occidentalis*. Left hind tarsus, ♀, paratype.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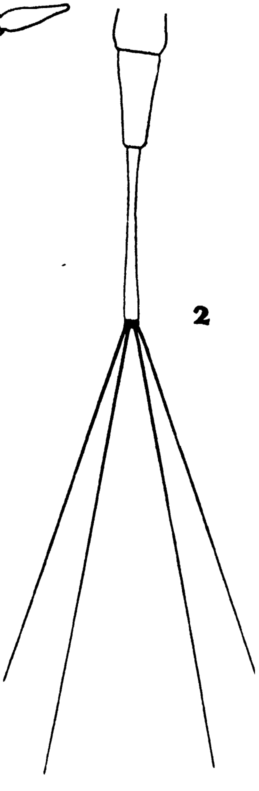
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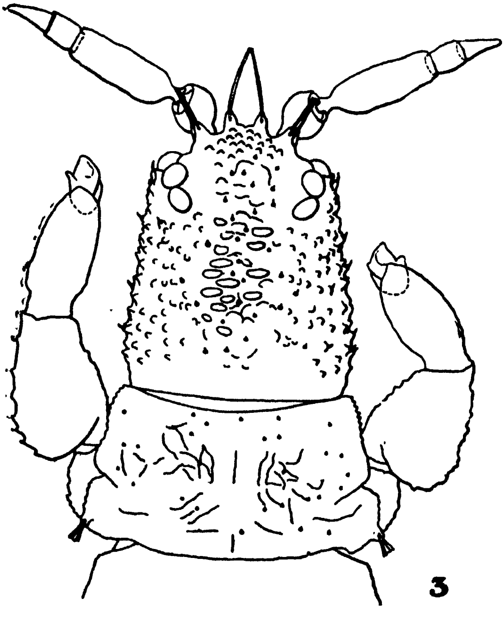
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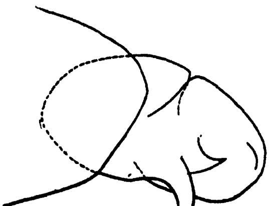
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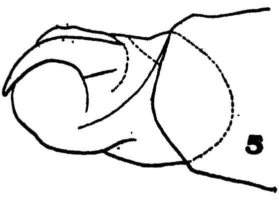
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Hood and Williams.

A CONTRIBUTION TO THE STUDY OF HIBERNATION IN THE LARVA OF THE EUROPEAN CORN BORER (PYRAUSTA NUBILALIS HUBN.)

H. L. PARKER,
Assistant Entomologist, U. S. Bureau of Entomology,
and
W. R. THOMPSON,
Entomologist, U. S. Bureau of Entomology.

The importance of variations of environmental conditions in determining changes in the seasonal history and economic importance of dangerous insects is now so generally recognized that the program of study of major pests practically always includes an investigation of the effect of the principal meteorological factors, with the object of establishing definite correlations between variations in the destructiveness or life history of the insect studied and fluctuations in climatic conditions.

In many cases investigations of this type have brought to light facts of considerable interest. It seems probable, however, that the problem is more difficult than has been supposed. Shelford,* in a recent and very suggestive paper, has shown that the simple methods hitherto in vogue are of doubtful utility and that the laws of development arrived at by the system of temperature summation are valid only within narrow limits. So complex, indeed, and so extensive, according to this author, are the investigations necessary to secure results of really practical value that they can rarely if ever be undertaken by the average group of entomological investigators.

Among the many factors which complicate the problem, Professor Shelford mentions particularly "the difference between different generations of the same species in respect to responses." In the Codling Moth, for example, "there may be as much as 20 per-cent difference in the length of the pupal life under the same conditions of temperature and humidity, as calculated or observed, due to preceding rainfall, variation of temperature, etc."

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* Journ. Econ. Ent., Vol. 19, No. 2, 1926.

There are, however, many cases, as yet, for the most part, imperfectly studied, in which the variation in the velocity of development from generation to generation is much greater and much more difficult to explain than in those cited by Shelford. Such are the insects which present at recurring intervals in their phylogenetic history the phenomena of arrested development which are usually classified roughly under the head of "hibernation" or "aestivation" but are more correctly designated by the term "diapause," proposed originally by Wheeler in connection with certain embryological phenomena and extended by Henneguy to cover resting stages at any period of the life history. It has been shown by recent experiments that insects which have passed into a diapause can be exposed for long periods of time to conditions inducing rapid transformation with normal individuals without any appreciable effect in so far as the velocity of development is concerned. The most general treatment of the matter seems to be that due to E. Roubaud, who published in 1922,* an extremely interesting paper giving the results of his investigation of the resting condition in the Muscoid diptera, among which he observed a number of cases of suspended development having apparently no relation to fluctuations in surrounding temperatures. More recently, an analogous condition, which K. W. Babcock has discussed from several standpoints in a series of excellent papers, has been found to occur in the life history of the European Corn Borer (*Pyrausta nubilalis Hubn.*)

In certain areas, both in Europe and in America, the Eurpean Corn Borer has usually two generations per annum. The larvæ of the first generation, issuing from eggs deposited in early spring, pupate during late July and August, emerging as adults in about two weeks. But the larvæ of the second generation, after reaching a condition of apparently complete development in the fifth stage toward the latter part of September, pass into a lethargic condition from which they do not emerge until the following spring. In other regions, however, the larvæ of the first generation, which reach the fifth stage rather late, instead of transforming, pass into the dormant condition like those of the autumn brood in the second-generation areas. It was at first thought that the condition of hibernation was directly determined by the prevailing meteorological conditions, but on investigation this hypothesis proved to be unfounded. It was found impossible to apply to the hibernating larvæ the results obtained from the study of the individuals of the summer generation. The experiments carried on by Mr. Babcock, as he has shown in his paper on the dormant period of *P. nubilalis*, demonstrated clearly that the diapause of the overwintering larvæ of this insect is something quite different from the lethargy induced by mere low temperature, and that the dormant individuals cannot be reactivated except in small members with a high rate of mortality by exposure to high temperatures, though every effort was made to reproduce as exactly as possible the conditions prevailing during the developmental period of the summer brood.

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* Bull. Biologique France Belgique, T. LVI, Fasc. 4.

The exact nature of diapauses, considered from the physiological standpoint, is as yet little understood. The only really comprehensive hypothesis that has been proposed is that of E. Roubaud. This author, whose opinion is based upon a number of ingenious experiments and arguments believes that the cessation of development is due to an auto-intoxication of the organism, whose excretory system is unable to keep pace with the accumulation of waste material which occurs in periods of rapid development, especially after several generations of uninterrupted multiplication. The period of repose at low temperatures, which according to Roubaud can be replaced in the case of certain Muscids by a number of different physiological stimuli, is considered by him to be a time of physiological purification, during which the excess of excretory material is little by little eliminated.

Among the observations mentioned by Roubaud in support of his hypotheses those connected with the histology of the excretory system in the hibernating species occupy an important place. He claims that there are well-marked differences between the hibernating and reactivated larvæ. At the beginning of hibernation the cells of the adipose tissue and the Malpighian tubes are filled with urate granules; in larvæ which have resumed activity these granules have disappeared, while the cells of the excretory organs have the appearance of elements exhausted by a prolonged period of intense activity.

The study of these results led us to hope that by examination of the excretory system of the larvæ of the corn borer it might be possible to identify the various phases in the development of the hibernating larvæ. We therefore made a series of careful dissections of overwintering specimens from all the most important regions in Europe, both during the period of hibernation and after emergence therefrom. In a considerable number of larvæ the Malphighian tubes were found to be irregularly swollen, the cells being filled with granular material. This was at first thought to be excretory in origin, but the application of the usual tests for uric acid gave negative results and on more careful examination it was found that the granules present were in reality parasitic protozoa which were subsequently determined by Dr. White of the Bureau of Entomology as Sporozoa of the Nosema group. So far as could be determined, there is apparently no relation between the presence of these organisms, which, in parentheses, seem to have little if any importance as pathogenic agents, and the phenomena of hibernation.

No other clear-cut differences were observed between the excretory organs of the hibernating and active larvæ of *P. nubilalis*. However, during a further series of dissections, undertaken chiefly in connection with the biology of the parasites of the borer, it was observed that as the spring advanced certain very definite changes occurred in the rudiments of the reproductive organs. These changes take place in the organs of both sexes. In the female larvæ they are difficult to follow accurately because of the minuteness of the ovarian rudiments in the caterpillars, but in the male larvæ they can be very easily studied. It was therefore decided to undertake a series of observations on the development of the genital organs in the male caterpillars, with the results described in this paper, which is offered not as a complete treatment of the problem of hibernation but simply as the outlinc of a method by which it can be attacked.

The rudiments of the male reproductive organs of *Pyrausta nubilalis* consist in the hibernating larva of a pair of small kidney-shaped bodies measuring approximately 0.75 mm. in length by 0.45 mm. in width, situated on the dorsal wall of the body cavity, ventrad of the heart, in the 8th body segment.

They are more or less firmly attached to the dorsal bands of adipose tissue and are held in place by the tracheal branches from the 8th segment. In each gonad can be distinguished 4 piriform compartments each of which opens at the smaller end, situated toward the mid-dorsal line, into a common duct, the vas deferens which is a long slender tube running posteriorly from the gonad along a line close to the middle of the dorsum until it reaches the 12th segment, where it bends abruptly downwards, passing under the tracheal trunk and terminating in a button-like prominence on the floor of the 12th segment. Between these button-like terminations of the vasa deferentia, on the floor of the segment, is found a spherical sack with a short, wide, tubular mouth attached to the ventral body wall. This sack, which is divided vertically into two equal compartments, apparently does not open to the exterior in the larval stage.

It is interesting to note that in 1762, in his celebrated treatise on the anatomy of *Cossus ligniperda*, the French entomologist Lyonnet gave a very accurate description of the larval gonads. He was not quite clear as to their exact significance, but strongly suspected that they were the rudiments of reproductive organs.

The histological structure of the gonad varies according to the age of the larva. In each of the four compartments is a large number of testicular ampullæ or spermatocysts of which several types can be distinguished in the prepupal larva. The youngest and smallest of the ampullæ usually lie along the wall of the distal extremity of the organ while the older, containing spermatozoa in various stages of formation, lie toward the small or proximal extremity. When the testicle is torn open in a drop of saline the ampullæ rush out and float freely in the liquid as independent and unattached bodies, varying in form from globular to elongate cylindrical according to the state of development. All of the cells in an ampulla appear to be in practically the same stage. The "zones of development" distinguished by the cytologists in the testicular tubes are thus represented in the gonad of the Lepidopterous larva by a series of ampullæ of different ages between which, however, no well-defined boundaries exist.

The youngest ampullæ form the germinative zone in which the primordial germ cells or spermatogonia multiply by division, but conserve their primitive dimensions. The next group constitutes the zone of growth in which the spermatogonia of the last generation increase in size and divide to produce the spermatocytes of the first order. The last two groups correspond respectively to the zone of division and reduction, in which are produced the spermatids, and the zone of transformation of the spermatids into the spermatozoa.

The resumption of activity by the hibernating larvæ is characterized by the swelling of the reproductive rudiments. As the organs enlarge, becoming in the process more rounded in outline, the distance between them diminishes and eventually they fuse together on their inner edges, assuming a spherical form. This latter condition is generally found in the prepupal larvæ, though development is sometimes retarded in certain individuals.

As the age of the larva can be estimated from the conditions of the gonads, it is important to be able to recognize the various phases of this development, We have therefore defined four stages in the growth of the organs and have classified the larvæ dissected into this arrangement. As the development of the testicles is gradual and continuous, the definitions given are necessarily somewhat indefinite. It is believed, however, that they will permit a classification of larvæ sufficiently accurate for the study of the life history of the corn borer.

In phase 1 the average testicle measures about 0.75 mm. in length by 0.45 mm. in width. It is reniform, with rather depressed and acute edges; the four compartments are distinctly visible; the organ in this stage is pearly white in color.

In phase 2 the average measurements are 1.0 mm. in length by 0.5 mm. in width; the form is about as in the first phase but is more rounded, the edges being much less acute; the four compartments are very distinctly outlined, being more clearly defined than in the preceding stage.

In phase 3 the average dimensions are 1.25 mm. in length by 0.5 mm. to 0.6 mm. in width. The gonad is now more oblong in outline and is greatly swollen; the edges are now rounded, the compartments still visible but indistinct.

In phase 4 the reproductive rudiment measures 1.75 by 2.0 mm.; the two testicles are now grown together and form an almost spherical mass, slightly flattened in the dorso-ventral direction. The general consistency is less solid than in the preceding stages, the walls being thinner and less resistant; the color is usually yellowish.

After a considerable number of gonads had been obtained and classified on the basis of their external morphology, they were sectioned for a cytological examination. Material for this work was obtained from various areas in France, including the one-generation districts of Lille, Paris, Angers in the north, the two-generation district of Hyeres in the southeast, and the transitional district around Auch in the southwest.

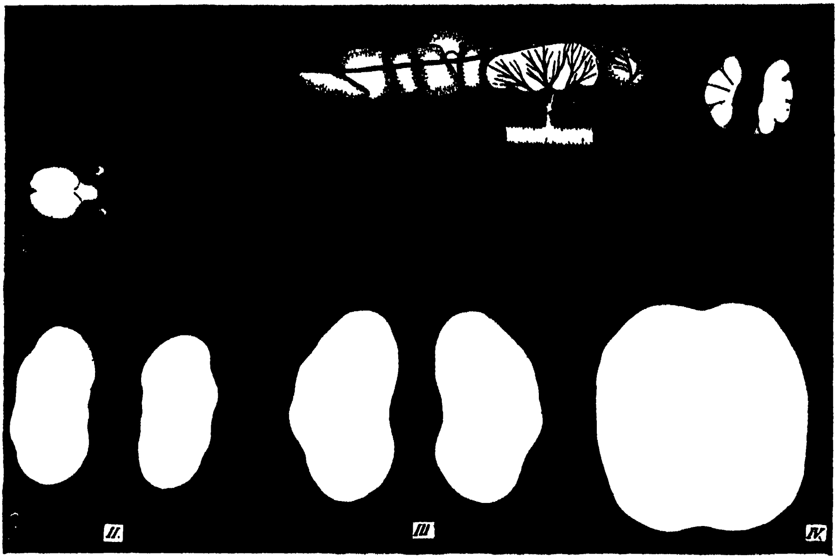


Fig. 1. Reproductive system of male larva of *Pyrausta nubilalis* Hubn. showing the testicle and duct of one side and the unpaired pouch in segment XII.
Fig. 2. Reproductive organs of male larva of *Pyrausta nubilalis* Hubn. Phase I.
Figs. 3–5. Reproductive organs of male larva of *Pyrausta nubilalis* Hubn. Phases II, III and IV.

The cytological condition of the phase 1 gonads was very uniform. The ampullæ contained only spermatogonia and spermatocytes of the first order. As the cells in the proximal region of the compartments are considerably longer than in the distal region, an increase in size has evidently taken place, but the only division figures observed were among the smaller cells. In this stage therefore there are represented in the testicle the germinative zone and the zone of growth excluding, however, the phase of division between the spermatocytes of the first and those of the second order.

The condition found in the phase 2 gonads was somewhat more variable than in the preceding phase, as the morphological characters utilized for its identification are necessarily rather ill-defined.

Generally speaking, this stage is characterized by an increase in size of the spermatocytes and by the appearance of division figures. We have made no attempt to decide whether the divisions observed are those giving rise to the spermatocytes of the second order or the maturation divisions. In any event, the appearance of the mitotic figures, which are very apparent and usually appear simultaneously in all the cells of a given ampulla, seems to be a definite indication that the larva has emerged from hibernation.

The phase 3 gonads are also variable but characterized for the most part by the appearance of spermatocytes containing spermatozoa in process of development, but still not perfectly formed, mixed with ampullæ still containing spermatocytes, many in various stages of division.

In the fourth phase the gonads contain little else but elongate spermatocytes filled with spermatozoa of which many are completly formed, though a few ampullæ in earlier stages are present here and there.

The result of dissections made to determine the main facts in regard to the development of the male reproductive organs are summarized in the following table, the most important data of which are represented graphically in charts I to VI. The proportions of the various stages present in each lot of larvæ have been calculated as percentages. As the number of larvæ dissected was in all cases inferior to 100, this procedure is of course open to serious objection as there is in fact no proof that the proportions of individuals in the various phases would have been the same in the remainder of the 100 larvæ required for the calculation of a true percentage. However, although the probable error in each individual case is very great, the general trend of the developmental processes as represented in both the charts and the tables is for the most part essentially the same, so that the data are probably sufficient to give a rough idea of the progress of events. In order to simplify the charts and tables, we have lumped the larvæ in phases 3 and 4 under one heading.

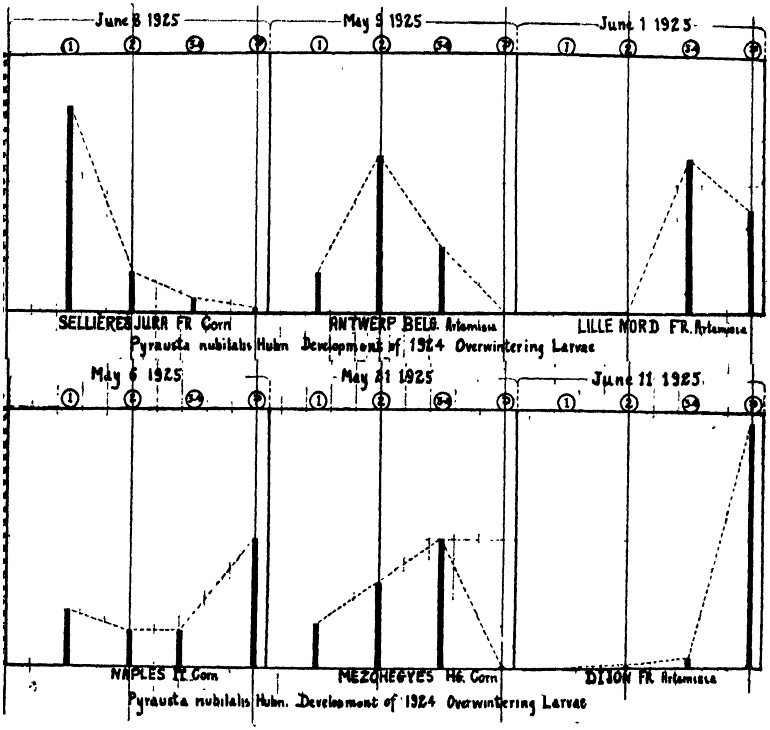
In spite of the fragmentary character of the data available, it is evident that the study of the reproductive organs affords an easy method of ascertaining with a fair degree of accuracy the stage of development of larvæ which it is quite impossible to classify by means of external characters.

TABLE I.

Locality	Type	Generation	Date	No. of larvæ examined	Phase 1.	Phase 2.	Phases 3 and 4	Pupæ
					%	%	%	%
Antwerp, Belgium	1-G	Winter	May 9, 1925	20	14.9	59.70	24.97	0.43
Lille, France......	1-G	"	June 1, "	3	......	......	60.0	40.0
Dijon, France.....	1-G	"	June 11, "	19	0.0	0.52	4.47	95.0
Sellieres, France..	1-G	"	May 8-9, "	20	79.0	14.9	4.8	1.2
Mezohegyes, Hungary........	1-G	"	May 21, "	18	16.6	33.3	50.0	0.0
Auch, France......	Transitional	"	May 9, "	24	95.9	4.1	0.0	0.0
" "	"	"	May 29, "	20	50.0	35.0	15.0	0.0
" "	"	"	June 9, "	14	6.9	41.5	48.5	3.0
Valence, France...	"	Summer	Sept. 2-3 "	45	91.8	2.2	0.0	6.0
Bergamo, Italy....	2-G	Winter	May 9, "	14	50.0	50.0	0.0	0.0
" "	2-G	"	May 14, "	58	8.5	18.6	70.7	2.2
" "	2-G	"	June 13, "	26	0.0	5.0	38.5	56.4
Naples, "	2-G	"	May 6, "	7	22.0	14.0	14.0	50.0
Hyeres, France....	2-G	"	May 9, "	22	44.4	40.2	13.3	2.0
" "	2-G	"	May 30, "	19	4.0	20.3	57.0	18.5
" "	2-G	Summer	June 30, "	5	40.0	60.0	0.0	0.0
" "	2-G	"	July 3, "	5	60.0	40.0	0.0	0.0
" "	2-G	"	July 7, "	19	5.25	5.25	89.5	0.0

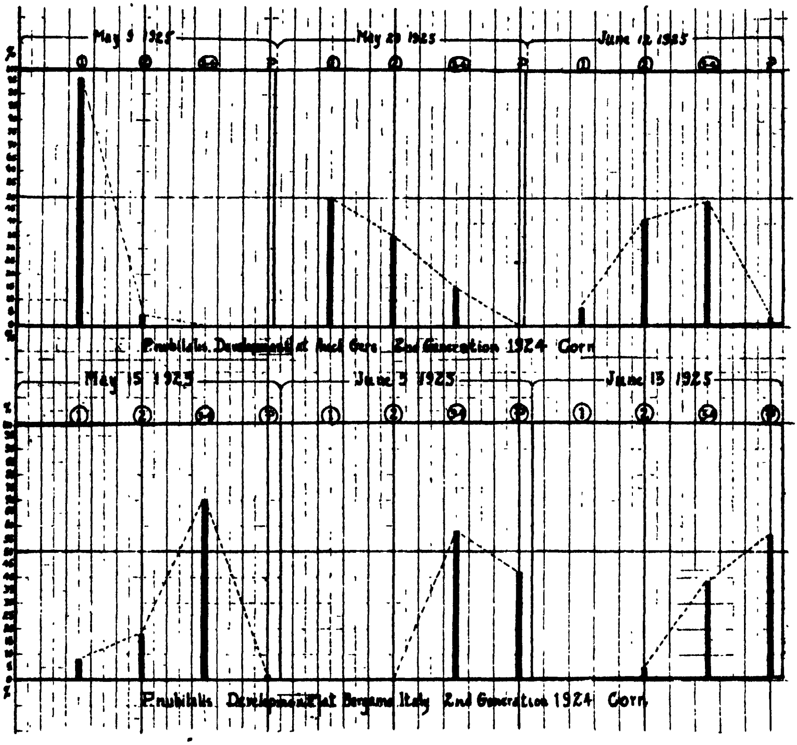
By suitable dissections we can thus detect a difference between the populations of various areas even before the time of pupation., A comparsion between the results obtained by the examination of the overwintering larvæ from Mezöhegyes, Hungary, on May 21, with those secured by a study of larvæ from Auch, France, and Gergamo, Italy, on May 9, is very suggestive in this connection.

Again, the examination of the gonads constitutes an easy and practical method of determining the approximate moment of emergence from hibernation and the progress of this process in any given area. It is probable that when the larvæ have emerged from hibernation their development is governed by the laws which normally prevail and can be expressed in terms of equations representing a few main factors such as temperatures and humidity. It is true that the actual moment of emergence from hibernation cannot be determined, but it is probable that when larvæ with reproductive organs in phase 2 begin to appear the majority of individuals have passed into a condition of physiological activity. It should thus be possible, by combining the method here described with suitable experiment, to predict the moment of the height of emergence from hibernation and to determine the laws of development from the time of emergence until the issuance of the adult insects. This would give us a sufficient grasp of the problem of the development of the overwintering larvæ for most practical needs.



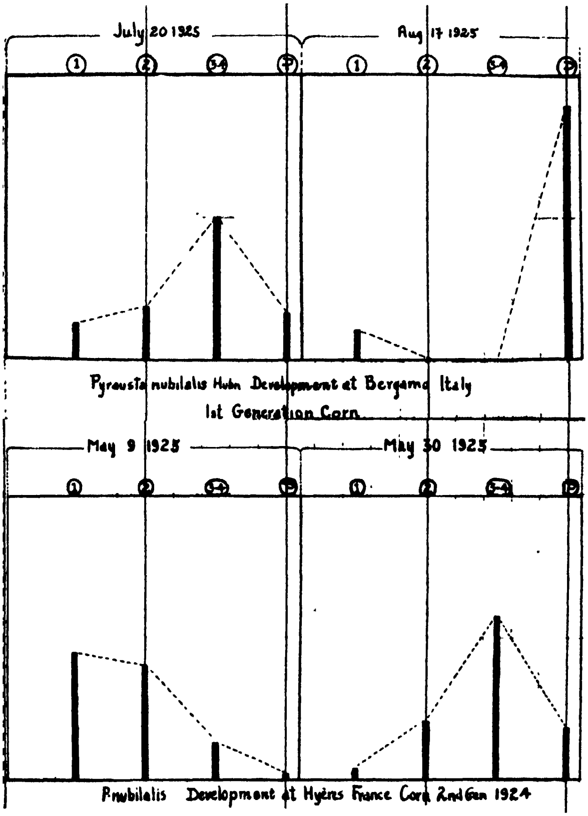
CHARTS I (above) AND II (below)

There are also indications that the study of the development of the larval gonads may throw some light on the problem of the causes of the hibernating condition. For example, some dissections of summer generation material made at Hyeres in 1925 show that in certain stage IV larvæ the gonads are already in phase 2 and that in the stage V individuals they develop very rapidly. On the other hand, in stage V larvæ examined even late in the summer, in a pure one-generation area, the gonads are all in the first stage. We may thus conclude that the inhibition of development affecting the imaginal organs is determined by factors operating at a fairly early stage in the larval life and is to a great extent if not completely independent of conditions prevailing in the height of the summer months, an idea already expressed by Mr. K. W. Babcock on the basis of his experimental studies. It is also



Charts III (above) and IV (below)

interesting to note that the larval organs continue to develop in the individuals predestined to hibernate until the point when they are completley formed; that the arrest of development affects only the imaginal rudiments, and that the histolysis of the larval organs begins only after the histoblasts have resumed activity. These facts would seem to indicate that the degeneration of the larval tissues preparatory to metamorphosis is in some way dependent upon the development of the imaginal tissues.



Charts V (above) and VI (below)

At all events, the difference in the rapidity of development of the gonads in the larvæ of the hibernating and non-hibernating types makes it possible by dissections to define fairly accurately the character of the larval population in transitional areas. For example, the dissection of 67 larvæ collected at Bergamo, Italy, in 1925, at a time when 17 per cent of the population had pupated, showed 11 in phase 1, 15 in phase 2, and 41 in phase 3. Now as the tables and charts indicate, by the time 17 per cent of the individuals have pupated practically no larvæ in phase 1 remain in a pure two- generation area. The continued occurrence of larvæ in this phase seemed explicable only on the hypothesis that a certain proportion of the population had passed into the hibernating condition. Collections made a month or so later supported this view. A lot of specimens collected on August 13-17 showed 89 percent pupæ and 11 per cent larvæ. Twenty six larvæ were dissected and in all of these the gonads were found to be in phase 1. On the date mentioned 79 per cent of the individuals in the field had emerged as adults, a fact which indicates that on this date the development of the summer generation in this region was nearly complete.

A good idea of the character of the larval population in a transitional area can thus be obtained by making a series of dissections of stage V individuals, neglecting preferably such specimens as have just moulted. The percentage of individuals having the gonads in phase 1 will probably approximate fairly closely to the percentage of hibernating larvæ in the region, especially if the dissections are made during the height of the period of pupation. By means of appropriate dissections it should be possible to evaluate with sufficient accuracy the character of a large number of transitional areas from year to year and thus gain an insight into the causes which determine the variations in life history in the different regions inhabited by the corn borer.

NOTES ON THE LIFE HISTORY, DISTRIBUTION AND ECOLOGY OF DIOTREPHA MIRABILIS OSTEN SACKEN.

J. Speed Rogers,
University of Florida.

Diotrepha mirabilis, new species and new genus, was described by Osten Sacken in 1878.* At the time the description was written he had no specimens before him, but based his account on his notes and memory of two specimens: one, designated as the type, taken by himself in Georgia in 1858; the other taken in Texas by a Mr. Boll. These two specimens constitute the only published records of *Diotrepha mirabilis* from the continent of North America, although Osten Sacken mentioned a third specimen, from Cuba, that he had seen in Loew's collection, as being probably the same species, and Williston† records the species from St. Vincent, where the collector, Mr. H. H. Smith, made the notes: "Abundant in forest glen 1000 ft.; near a stream; Sept. Alights on the lower sides of leaves."

During the past several years I have had the opportunity to observe, collect, and rear this cranefly in several localities within the United States. On June 14, 1921, while collecting with Dr. C. P. Alexander, in Jefferson County, Indiana, we took some six specimens while sweeping the vegetation along a small, shady, marshy, spring rill that ran through a beech woods. In June of the following year, several more adults were taken from the same situation and some larvæ and pupæ, of what proved to be this species, were discovered in a wet, rotten, sweet gum log that lay at the margin of the rill.

In Florida, *Diotrepha mirabilis* has been taken in four widely separated localities in the northwestern and central parts of the state. Washington County, a single teneral specimen from a "bay-head" (a swamp of mixed broad-leaved trees), June 18: Liberty County, a specimen from the shaded bottom of a beech-savarn-magnolia ravine of the Apalachicola River, and abundant and emerging in numbers in a creek-bottom gum swamp, July 26 and 27; Alachua County, from a black gum swamp and from two separate marshy, shaded, brook ravines, March, April, May, June and August; Marion County, from a low hammock along a creek bottom, April 4.

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* Osten Sacken, C. R., Catalogue of the Diptera of North America, Second Edition. Smithsonian Misc. Col. 270; Washington, 1878.

† Williston, S. W., On the Diptera of St. Vincent (West Indies); Trans. Ent. Soc. London for 1896, Part III.

Intensive collecting in other localities in Florida and in Georgia, North Carolina, and Tennessee have, so far, failed to discover this fly.

The existence of the imago is brief, even for a cranefly. Out of more than a hundred that have been reared, none have lived for more than 48 hours and this in cages where other craneflies, (*Epiphragma solatrix*, *Dicranomyia rara*, *Atarba picticornis*, *Teucholabis complexa*), emerging from the same rotted wood were active and vigorous from four to six days. When copulation takes place soon after emerging, the duration of adult life is even more brief. In only two cases out of more than twenty did either member of a pair live more than eighteen hours after copulation was completed. Both of these were females. Collection in the field, on the only occasion when adults were taken in numbers, consisted of a large percentage of teneral individuals and most of the others appeared to be but recently hardened.

The adult appears to be closely restricted by atmospheric moisture. In all situations in which adults have been found deep shade and saturated earth combine to make the surrounding air very moist. In a narrow, shaded brook ravine on the University of Florida Campus, careful collecting has been done at frequent intervals. All the flies taken have been from about or beneath dense fern clumps that grow from saturated soil along the bottom of the ravine. In this narrow zone adults have been taken for a considerable distance along the ravine, but none have ever been found outside of this tenfoot wide, wet strip, although the rotten wood from which scores of empty pupa skins project lies near the outer margin of the wet area.

In the fall, winter and spring of 1923–1924, Dr. Frank A. E. Thone, then Professor of Botany at the University, ran a series of atmometers along a cross section of the ravine. This line included the area from which *Diotrepha mirabilis* had and has been taken, and the drier slopes to either side. The atmometer readings showed marked and persistent evaporation differences between the narrow, moist bottom of the ravine and the slopes to either side and although the evaporation rate increased farther up the slopes and on the level ground at the top of the ravine, the most marked increase was that from the ravine bottom to the lower slopes. Apparently this region of marked evaporation increase coincides with the limits of the fly's habitat.

Nearly all of the flies that have been observed in the field have been at rest, clinging to the under side of leaves and fronds. When disturbed, they fly upward until they come into contact with another surface. Should the fly chance to touch the upper surface of a leaf, while in flight, it alights and at once walks over the edge to come to rest suspended from the lower surface. After some preliminary bobbing, hold is maintained with meso-and metathoracic legs, the body hanging well away from the leaf and parallel to it and the prothoracic legs projecting downward and forward, beyond the body.

In flight the fly resembles a bit of thistledown drifting in the air. Although the small wings move rapidly and give good progress, the long trailing legs and body make any breeze cause considerable leeway. For this reason the precise spot on which the flying insect will come to rest, seems partly a matter of chance.

On several occasions I have observed a small Asilid capture individuals that were in flight.

Strong light is avoided. Full sunlight falling upon or reflected upon a resting fly will cause it to move, but the light of ordinary north shade is not avoided. At night females will come to a lighted sheet, even for a distance of a hundred yards.

I have never observed *Diotrepha mirabilis* to feed, but one individual was observed with the mouthparts applied to a drop of water on the underside of a leaf. The mouth parts were in contact with the drop of water for nearly a minute and then the fly resumed the usual resting position, lowering the body well away from the leaf and the drop of water.

A pair in copulation were observed in a gum swamp in July. The female clung to the underside of a small leaf, at a height of about six feet. She was hanging by the two anterior pairs of legs, while the metathoracic pair hung limply down. The male hung head down with no other support than the clasp of his genitalia. In cages in the laboratory, the flies copulate freely and the whole process can be followed with considerable detail. When a male and a female are put into the same cage, both rest quietly from the top or sides of the cage with only occasional changes of position, until such movement results in the two flies coming in contact. Even the slightest touch of any part of the bodies or their appendages serves to arouse the male to immediate activity. He flutters about until he is again in contact with the female and as rapidly as possible takes a position in which his body is dorsad to hers, that is, parallel to hers, but farther out from the support. his legs straddling her body to obtain a foothold on the same support to which she clings. At the same time the basistyles of the male are spread open into a shallow V and the dististyles are opened to their widest extent so that they project directly caudad and are parallel. The whole structure forms a pair of widely opened forceps. The long slender abdomen of the male bends into the shape of a shallow fish hook, the genitalia at the apex, so that although his thorax is dorsad to the thorax of the female, the middle of his abdomen passes ventrad to the female's abdomen and the distal third of his abdomen curves sharply dorsad again to bring the opened forceps towards the female's abdomen from beneath. The forceps are moved about vigorously, feeling for the female's abdomen. The slightest touch on the inside of the forceps causes them to snap shut, the basistyles folding together and each dististyle snapping against its basistyle like a knife blade into the handle. Frequently the forceps shut upon the female's or his own legs but in such a case the forceps are quickly opened again and the feelng about is resumed. Once the forceps close about the female's abdomen, usually in the region of the fifth to seventh somite, the hold is retained, although loosened enough to allow the encircling ring of basistyles and distisyles to be quickly slid caudad along her abdomen to the base of the ovipositor. Here the flexed dististyles meet or overlap at the base of her ninth abdominal tergite, and their position is retained while basistyles are still pulled caudad, with considerable stretching, around the tips of the sternal valves of the ovipositor. In executing this movement the abdomen of the male is sharply bended and his feet are moved backward to carry his body farther back. As the basal angle of the forceps slips over the sternal valves of the ovipositor, the dististyles are strongly flexed and the genital chamber of the male is drawn over the sternal valves as a scabbard might be thrust over a sword. In some cases this part of the process causes some difficulty and considerable effort is made before the sternal valves slip properly into place. Apparently, coincident with the enveloping of the sternal valves, the penis is inserted but the whole movement is rapid and observation is difficult because slight movements on the part of both flies makes it impossible to maintain a sharp focus with a binocular, or even a hand lens. Once the sternal valves of the ovipositor are properly fitted into his genital chamber, the male lets go his foothold and slowly bends downward, at the same time rotating the anterior end of his body, to hang head down, supported only by the hold of his genitalia. Should his feet chance to come into contact with some support he may take hold, but frequently does not.

The obtaining of the copulatory hold takes from one to three minutes and is marked by considerable exertion and activity. Once the male has turned about to hang head down, or to face in the opposite direction, both flies rest quietly for thirty to forty minutes. At the end of this time both become restless and begin to move about. The male may turn back toward an upright position, using the female's body as a foothold to scramble back to the overhead support. Often, however the movements of the female bring the male's sprawling feet into contact with some supporting surface before or while he attempts to reach the overhead support. Once the male has his feet in contact with a solid support the flies quickly separate with little effort. Once separated both flies rest quietly for some minutes, after which the male begins to occasionally walk or fly about, ready to repeat the process with another, or the same, female at the slightest contact. In, at least, one case the second female laid fertile eggs and had not paired with another male.

The female usually waits until dusk or night to begin ovipositing. A fertilized female that seems sluggish in the afternoon will often be found actively at work, laying eggs when a flashlight is turned on her cage at night. Some females, however, begin ovipositing in the daytime. In ovipositing. the female climbs slowly and awkwardly over the pieces of rotten wood in her cage, touching her ovipositor to the surface of the wood from time to time. After touching some spots, the tips of the ovipositor are pressed more firmly against the wood and a slow, rythmic movement of the legs and abdomen begins, that forces the tips of the ovipositor beneath the surface of the wood. There is then a pause, the valves of the ovipositor open slightly, another pause, and the ovipositor is withdrawn without appreciable effort. In some instances the chosen spot is abandoned after an effort to force the ovipositor into the wood. In nearly all cases the chosen spot is on a vertical or nearly vertical surface of the wood. The egg is placed at a depth of about a millimeter and usually lies at the juncture of the most rotten and more sound wood.

All of the wood from which larvæ or pupæ have been taken, or from which adults have been reared, has been in a similar stage of decay. It is saturated or almost so, the bark gone, and with a thin black surface layer of moist, rotten, wood-dust. Beneath this thin sludge the wood still shows the annual rings, but these readily separate into flaky pieces with the pressure of a finger nail. Deeper, the wood may be much more firm. Magnolia, black gum, bay, sweet gum, and red maple in this stage of decay have been found containing the larvæ or pupæ of *Diotrepha mirabilis.* The broken ends of the logs and large branches frequently show areas of wet spongy decay, that are green with thin patches of algæ and these areas are also occupied by the immature stages. Wood in the proper stage of decay, whether large trunks, or twigs the diameter of a lead pencil, may be inhabited. In the larger logs, frequently only a narrow zone, next to the wet soil, is inhabited, the upper parts of the circumference still too sound to be available. In a magnolia log that was observed in 1923, 1924 and 1925 the inhabited zone has crept upward with the progress of decay from the bottom third of the circumference in 1923 to the top area in 1925, the bottom, by that time, too rotten for occupancy. The inhabited wood often shows signs of former use by *Passalus cornutus* and other wood boring beetles, but these have disappeared or are far deeper within the wood, by the time *Diotrepha mirabilis* appears. Contemporary inhabitants with *Diotrepha mirabilis* are the craneflies: *Epiphragma fascipennis* (Indiana); *Epiphragma solatrix*; *Elephantomyia westwoodi*; *Dicra-*

nomyia rara; *Atarba picticornis*; and *Teucholabis complexa*, although several of these are found in wood in other stages of decay as well.

The larvæ and pupæ are found close to the surface of the wood, either the circumference, ends, or in crevices. They have indefinite, short burrows, usually between two of the rotted annual rings, but sometimes through the frass of an old Passalus cornutus burrow. Nearly always the burrows and the larvæ and pupæ are parallel to the nearest surface of the wood. Often the burrows have openings to the surface at one end but the surface is so spongy and soft that it is impossible to be sure whether openings are always present or not. These burrows are not over three or four times the length of the full grown larva and are lined with a thin, opaque, delicate sheath. In the burrows of the young larvæ this sheath is scarcely evident but in the case of older larvæ it forms a complete lining of the occupied part of the burrow, and pupation takes place within this sheath.

The immature stages are apt to be very numerous in wood in which they occur at all. Thirty larvæ and pupæ have been taken from an area three inches by one half inch, all within two millimeters of the surface. The larvæ are very sluggish but move when uncovered or touched, forward or backward in the burrow. Movement is accomplished mainly by dilating the terminal segements of one end and then lengthening the rest of the body; the terminal segments of the other end are then dilated and the rest of the body shortens, a series of alternating pushes and pulls. Creeping welts are present and are probably used, but the greater part of locomotion is due to the process described above.

Both the larvæ and pupæ are exceedingly delicate and with the best of care at least half of those found are injured in removing them from the wood.

The food of the larvæ, as indicated by smears from the digestive tract, consists of the soft rotted wood and the microscopic lower plant life that grows in or from it. Among these lower plants are desmids, diatoms, and the filamentous algæ Gleothecia, Nostoc, and Rivularia.* Some larvæ have been reared from egg to maturity in wood which showed very little

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[1] Identifications made by Prof. M. D. Cody, University of Florida.

microscopic plant life, but these larvæ were paler in coloration and smaller at pupation than larvæ taken full grown from rotten wood in the field.

In Florida there are two generations a year and, although the seasons are not clear cut, the adults are most numerous in March and April and in July and August. In the breeding cage, eggs laid by adults that emerged in August were minute larvæ in September, were full grown larva in late February, and emerged as adults from March 20 to 30. Larvæ of about the same size as the September larvæ, above, were taken from a rotten log in late April, 1926 and adults appeared in July and August. Because of their delicate structure and wood-burrowing habit, it is difficult to follow the development of the larvæ. Shortly after hatching, the larvæ have a length of from 3 to 4 mm.; in two months the length is from 8 to 9 mm.; when full grown from 10 to 13 mm. The younger larvæ are almost transparent and very slender, but the markings and shape of the spiracular disk, to be described below, are characteristic, although the coloring is faint.

Several full grown larvæ, placed with wood pulp between glass slides that were separated by little more than the diameter of the larvæ, were observed to pupate. The larvæ become quiet and the color fades to a dirty yellowish white. About two days after the larvæ become quiet, the faint outlines of the pupæ become visible, and at about this time the larval skin splits in the thoracic region with the emtpy head capsule still enclosed in the first thoracic segment. Slight movements of the pupa serve either to withdraw the pupa farther from the larval skin or else to force the skin caudally from the thoracic region. Probably both forward movements of the pupa and wriggling, that forces the larval skin backward, serve to free the pupa from the larval skin, although after four or five days in the pupa stage only the head, thorax and first few abdominal segments are free from the larval skin, the empty end of which doubles back over that part of the abdomen still encased, like the fingers of a glove that are turned wrong-side-out as they are pulled from the fingers. In the last few days of pupal existence the movements are more frequent and vigorous, and usually the entire pupa is withdrawn from the crumpled larval skin before the period is ended. At the same time the pupa progresses anteriorly some 8 to 15 mm. from the position occupied at the time pupation began. This progress of from 8 to 15 mm. was made in the soft wood pulp. In natural burrows the progress of the pupa as judged from positions in which early and late pupæ are found, is often greater and ends with the matured pupa projecting about one third of its anterior end from the surface of the wood. Usually the larval skin and head capsule can be found in the burrow from 5 to 10 mm. caudad to the empty pupa skin.

Only one specimen, of those placed between glass slides, whose change into a pupa was timed, survived the entire pupa stage and emerged. This was noted as a quiet and pale larva at 4 P. M., March 14. At 9 A. M., March 17, the faint outline of the pupal head and thorax were visible and by noon of the same day the larval skin was turned back as far as the wing pads. A female completed its emergence (free of the pupa skin) at 6 P. M., March 25.

The actual emergence of the adult from the pupa skin takes from 5 to 15 minutes. The head and thorax quickly appear after the initial splitting of the skin, but the abdomen and legs are slowly withdrawn by periodic rythmic rocking of the body backward and forward and by waves of expansion and contraction that pass caudad along the abdomen. Until the legs are free the emerging body projects vertically above the pupa skin, but once the legs are free of their sheaths, the body is bended over until the feet take hold of the surface of the wood and the rest of the abdomen is then smoothly withdrawn. In less than an hour the swollen and elongate abdomen assumes a normal size but full adult coloration and hardening requires about two hours. Flight is possible long before the abdomen has reduced to normal size, but if undisturbed the female rests quietly near the empty pupa skin until normal size is attained and considerable hardening has taken place. Frequently the maturing females are found by older males, and copulation takes place before the female is fully hardened and colored.

DESCRIPTIONS OF THE IMMATURE STAGES.

The Larva (Full Grown).

Length 13 mm.; diameter at second thoracic segment, 1 mm.; at third abdominal segment, 0.8 mm.; at spiracular disk 0.9 mm. Form slender, very elongate, terete or but slightly flattened dorso-ventrally. The slight enlargements at the thorax and caudal end are abrupt. The integument is colorless and transparent save for a faint brownish cast in the thoracic region; thickly covered with an appressed, pale pubescence. In the living larva the massive, dark brown head capsule shows thru the integument and against this background the pubescence of the first thoracic segment has a hoary reflection. In life, the first six and a half body segments are colored a transparent lobelia violet* by the body fluids; in the seventh segment this color is displaced by chrome yellow, due to the fat bodies that show through. The chrome yellow continues posteriorly to a narrow band of lobelia violet just cephalad of the spiracular disk. When the larva moves the boundaries of these colors shift somewhat with each expansion and contraction. When killed the body coloration changes to a uniform, opaque, yellowish white. Narrow creeping welts extend across the tergites and sternites of the second to seventh abdominal segments, inclusive, just caudad of their cephalic margins. These welts are slightly elevated, especially at the mid-dorsal and mid-ventral lines, and bear three cephalic and two caudal rows of minute setae. The setae are appressed and those of the cepahlic and caudal rows point cephalad and caudad, respectively. The setae of the opposite inner rows are distinctly larger than those of the three (two cephalic and one caudal) outer rows.

The spiracular disk (Fig. 1 b), flat and squarely truncating the axis of the body, has a diameter slightly greater than that of the body. It is composed of four broad, petal-like lobes that divide the face of the disk into subequal quadrants, separated by narrow, pale lines. Each quadrant is dark chestnut brown, save for a narrow, pale border at or near the outer margin of each quadrant. The extreme outer margins of the dorsal quadrants are dense blackish brown. The lower "quadrants" are larger than the upper, their angles extending dorsomesad past the center of the disk. The spiracles are elongate elliptical, the inner ends dorsad to the lateral and separated by about half the length of one spiracle. They lie at the inner ventral margin of the dorsal quadrants. The entire arc of each quadrant-like lobe bears a close-set single row of long, stout, pale brown hairs that curve slightly cephalad; except at the middle of the arcs of the ventral lobes, where these hairs are shortest, they are about as long as half the diameter of the disk.

The head capsule (Fig. 1 a), is compact and massive. Its sides are formed by two mussel-valve-like, chitinized plates; the dorsum is a triangular chitinized plate, margined by two heavier rods of chitin

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[1] Ridgway, Robert, Color Standards and Nomenclature, Washington, 1912.

whose divergent cephalic ends fuse with the lateral plates in areas of heavy chitinization, and whose convergent caudal ends are separated by a narrow cleft in the caudal end of the dorsal plate. The labrum is large, broad, semicircular posteriorly; clothed with long pale hairs; two widely separated papillæ, bearing several short hairs, are situated at about mid-length. Antennæ short; basal joint cylindrical, stout, with scattered long pale hairs; at its apex bearing a short, slender, elliptical second joint and several minute, slender papillæ. The mandibles (Figs. 1 d, 1 e) are heavily chitinized, dark brown, massive and comparatively large. At the apex of each mandible are two conical, blunt teeth, the ventral one the larger and curved ventro-mesad; the ventral margins bear four flattened, broad cutting teeth. The maxillæ are large, having the appearance of inflated sacks, and are bilobed distally. The mesal lobes are densely hairy on their inner faces; the outer surface of the mesal lobes and the entire surface of the lateral lobes are clothed with long pale hairs. The lateral lobes are more slender than the mesal and each bears near the apex of its lateral margin a short, broad, cylindrical palpus, that in turn bears a number of minute papillæ. The large mentum (Fig. 1 c) is almost entirely cleft from behind, the cleft ending just before the apex of the median tooth. On either side of the median tooth are four, flattened, triangular teeth, the median pair as large and extending as far cephalad as the median tooth, the three lateral pairs progressively smaller and more caudad. The two halves of the mentum are borne at the end of two chitinized bars that extend forward from the ventral margins of the lateral plates. The hypopharynx bears on the anterior margin of the anterior plate eight equal, small, rounded teeth. The posterior plate bears no teeth, that I can discern, but is slightly thickened on the anterior margin.

The Pupa.

(Fig. 2, a, b, c, e).

Length, males 8 mm.; females 10 mm. Diameters at the base of the wing pads, female pupæ; dorso-ventral, 1 mm.; dextra-sinistral, 0.9 mm. Male pupæ slightly smaller. Form very slender and elongate. From the maximum diameter at the mesothorax, the body tapers evenly toward the caudal end. Color: head and thorax buckthorn brown, with the wing pads, and eyes chestnut brown; the leg sheaths range from light orange yellow at their proximal ends to chestnut brown at the tarsi. The abdomen is a striking orange yellow, becoming dark reddish yellow late in pupal life. The head is small, slender; the eyes relatively large, in the male almost contiguous above and below, in the female separated by about half their width. The cheeks gibbous laterally, their latero-ventral angles prolonged and flattened. Labrum sub-quadrangular, slightly expanded before the rounded apex; labial lobes broad and blunt, their inner margins contiguous. Maxillary palpi conical, thick at the bases, the apices curved dorso-laterad to the ventro-laterad tips of the cheeks. Cephalic crest absent, this region a smooth rounded plate, lower than the bases of the antennæ. The antennæ arise at the inner dorsal margins of the eyes, their basal two fifths stout and angulated, the distal three fifths more slender and with few angulations. Apices of the antennæ opposite the wing bases.

Thorax slender and almost cylindrical, except for the cephalic margin of the mesonotum, but slightly chitinized. The large, flat pronotal breathing horns extend slightly cephalad of the head and lie in approximately sagittal planes to the body. Each horn is triangular in outline, the line of insertion on the pronotum forming the acute but truncated apex of the triangle, the elongated distal margin of the horn forming the triangle's base. The lines of insertion of the two horns are parallel and are separated by more than a third of the width of the pronotum, but the dorsal and ventral angles of the distal end of the horns curve mesad so that their inner faces are concave. Along the entire rounded edge of each horn runs an irregular line of minute, unchitinized, rounded papillæ. No pores are perceptible. The mesonotum is elongate; its crest is unornamented but forms a rounded, chitinized edge that projects over the caudal margin of the pronotum. Wing pads narrow and elongate, ending just before the caudal margin of the second abdominal segment. Tarsal sheaths slender and elongate, ending opposite the cephalad half of the fourth abdominal segment; their apices level.

The abdomen with the integument very delicate; caudal margins of tergites and sternites slightly more heavily chitinized; tergites and sternites of segments three to six, inclusive, bear a row of minute, caudally directed setæ. Lobes of the eighth sternite not evident. Female cauda (Fig. 2 c) with the blunt conical sternal valves slightly longer than the tergal valves; the latter abruptly truncated. Male cauda with two dorso-lateral blunt lobes that project caudad and two much longer ventro-lateral lobes that extend dorsad between the dorso lateral lobes. Between the bases of the ventro-lateral lobes, a short rounded papillus projects caudad.

The above descriptions are drawn from about 50 larvæ and pupæ collected in Jefferson County, Indiana and in Alachua and Liberty Counties, Florida, now in the collection of Museum of Zoology of the University of Michigan.

On the basis of adult structure, Dr. Alexander has placed the genus Diotrepha, provisionally in his subtribe Antocharia of the tribe Limoniini*. In the structures of the pupa and, especially, of the larva, *Diotrepha mirabilis* shows a much closer apparent resemblance to Limonia than to Antocha. However, the habitat of the immature stages of *Diotrepha mirabilis* is very like the habitat of the immature stages of Limonia and is strikingly different from the habitat of the larva and pupa of Antocha which live, attached to stones, beneath the surface of flowing water. No doubt, much of the structural similarity between the immature stages of Limonia and Diotrepha is due to this close similarity of habitat and the entirely different types of habitats occupied by Diotrepha and Antocha necessitate the differences in mouth parts, respiratory organs and other structures.

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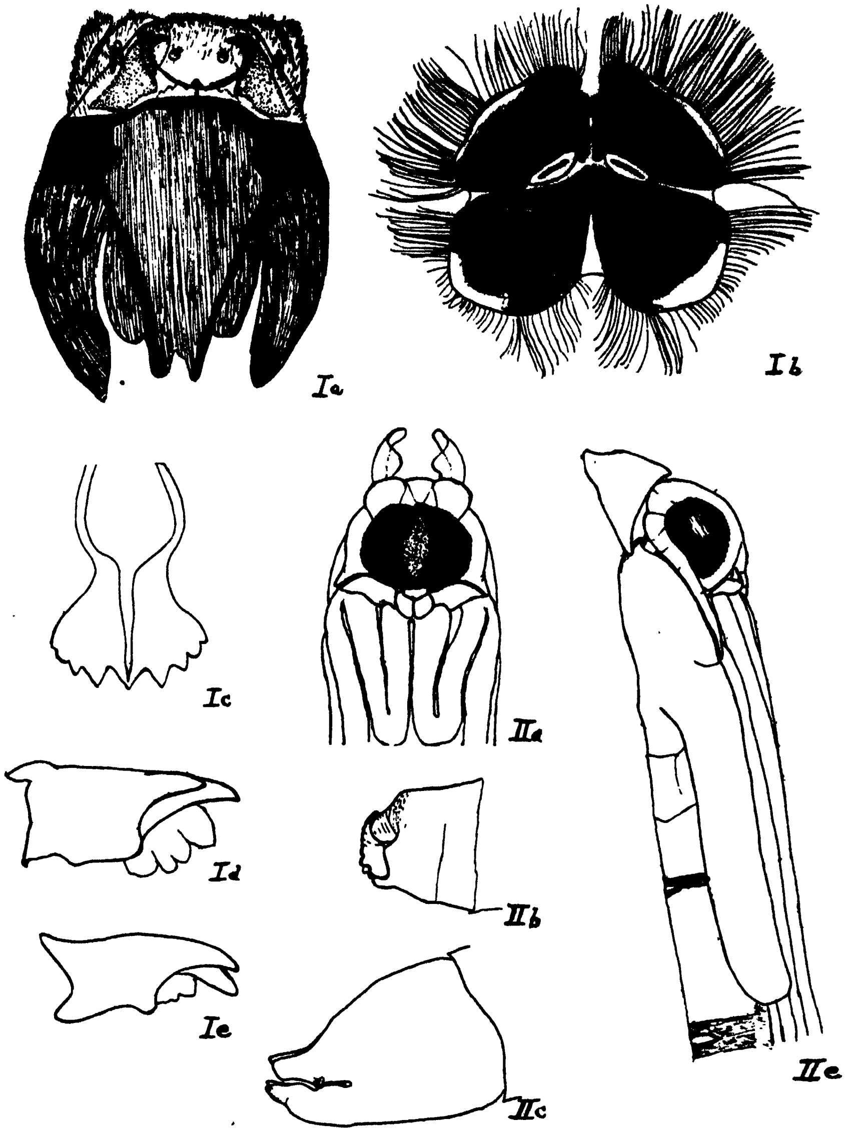
* Alexander, C. P., The Crane-Flies of New York, Memoir 38, Cornell Univ. Agr. Exp. Sta., Ithaca, N. Y., 1920.

In defining the subtribes of the Limoniini, Dr. Alexander took into account both adult and immature characters and held that the subtribes Antocharia, Limonaria and Ellipteraria are closely related. In spite of apparently very great differences in the larva and pupa of Antocha, they have many fundamental resemblances to those of Limona: general type of the head capsule and mouth-parts, structure of the creeping welts, character of the integument, the proportions and chitinization of the pupa. In view of the evident relationships shown by the adult stages of Diotrepha and Antocha, I believe that the similarity between the immature stages of Diotrepha and Limonia does not indicate so much that Diotrepha should be placed in the Limonaria, as that the Antocharia are very close to the Limonaria and that the pecularities of Antocha's larva and pupa are due to their unique (for a cranefly) habitat. Dr. Alexander has already expressed his belief that many structures of the larva and pupa of Antocha are adaptive rather than phylogenetic and the resemblances of Diotrepha's larval and pupal stages to Limonia's offers, I believe, some evidence for that probability.



Larva and Pupa of Diotrepha mirabilis Osten Sacken.

I a—Head capsule of larva, dorsal view.
I b—Spiracular disk of larva, caudal view.
I c—Mentum of larva.
I d—Mandible of larva, mesal view.
I e—Mandible of larva, dorsal view.
II a—Head of pupa, ventral view.
II b—Cauda of male pupa, scale larger than IIa and IIe.
II c—Cauda of female pupa, scale much larger than IIa and IIe.
II e—Head and thorax of pupa, lateral view.

THE HOST-SELECTION PRINCIPLE AS APPLIED TO BRUCHUS QUADRIMACULATUS FAB.

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One of the most interesting principles recently developed in economic entomology, if not one of the most far reaching in its application is the host-selecting principle. As defined by Dr. A. D. Hopkins(1) this principle is that an insect "species which breeds in two or more hosts will prefer to continue to breed in the host to which it has become adapted."

By carrying this principle to its extreme hypothetical conclusion we would have developed from the progeny of one polyphagus insect species, a great number of distinct species each in turn being monophagus. To use a specific illustration the progeny of a four-spotted cowpea weevil, *Bruchus quadrimaculatus* Fab., which had emerged from a blackeyed cowpea *Vigna sinensis*, if they by choice, accident, or by human manipulation were to breed in the chick pea, *Cicer arietinum*, the broad windsor, *Vicia faba*, or any one of a dozen other kinds of seeds, would become distinct species breeding in only one kind of seed.

In order to obtain more evidence relating to this principle the writer began a series of experiments in 1919 with Bruchids which normally breed in beans, *Phaseolus vulgaris*, and cowpeas, *Vigna sinensis*. These weevils offered material which was very well adapted to the conduct of such experiments. The four-spotted cowpea weevil, *Bruchus quadrimaculatus*, which in California breeds almost exclusively in blackeyed cowpeas but which is known to breed in many varieties of cowpeas and other seed, produces several generations each year thereby giving an opportunity to study the inherited tendencies.

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* This article in a somewhat different form was a thesis presented to the department of biology, University of Southern California, in partial fulfillment of the requirements for the degree of Master of Science.

The writer wishes to express his thanks to Dr. E. A. Back and Dr. A. D. Howard for valuable suggestions, and to Messrs. P. Simmons, A. H. Amis and C. K. Fisher for painstaking assistance in examining the seeds and checking results in the experiments.

HISTORICAL.

Apparently very little work has been done on the adaptation of insects to their host plants or their variations due to their selection of host plants, however, the few references found are well scattered through European and American Entomological literature.

According to Craighead (2), Dr. Walsh (3) (4) is probably the first entomologist to state definitely this principle in concise wording. The following quotation (3) is taken from pages 405-406-407, Volume III:

"Even with the little we know of the Laws of Inheritance, we might infer a priori, that from peculiar circumstances a Phytophagic Variety, including both the sexes, has fed for a great many generations upon one paticular plant of the number inhabited by the species to which it belongs, it would be likely to transmit to its decendants in the imago state a tendency to select that particular plant upon which to deposit its eggs. We know, for example, that young pointer puppies when taken into the field, will frequently point game without any instruction or training whatever, though the habit of pointing is clearly acquired and not a natural habit, and must have been transmitted to them from their ancestors in virtue of the Laws of Inheritance. If then, it should happen that owing to the presence of but a single species of the plants ordinarily fed upon by a particular species of insects, or to other causes, eggs have been uniformly deposited by a Phytophagic Variety upon the same plant for an indefinitely long series of generations—say fifty, or a hundred, or a thousand—and the female has in no case intercrossed with a male belonging to a different Phytophagic Variety, then it is probable that habit will have become a second nature, and that it will cease to be possible for that insect, which by the supposition has fed upon that one plant for a very long series of years, to feed upon any other plant than that to which it has become habituated by the Laws of Inheritance.

"But before this point is reached, another series of phenomena will have come into play. Every naturalist is aware that species often run into what are known as geographical races, when separated into two or more distinct groups by physical barriers. Just so the Phytophagic Variety, having by the supposition been isolated from the other members of its species, will often run into what may be called Phytophagic Races, and finally, perhaps, acquire a moral indisposition, or a physical inability, to intercross with the other members of the species. It will then have become what I propose to call a Phytophagic Species, distinguished from the other members of the species to which it originally belonged by certain slight peculiarities of size, or of coloration, or occasionally even of structure, just as geographical races are so distingiushed. But there will be this essential difference between the two cases: Geographical Races are connected, or supposed to be connected, by all the intermediate grades, and may therefore be reasonably concluded to intercross on the confines of their geographical boundaries. Phytophagic Species are not so connected, and by the supposition they do not intercross, or, at all events, only in very rare instances, as is sometimes the case with what are allowed on all hands to be distinct species.

"According to my views, Phytophagic Species are as truly distinct species as those which differ by much stronger characters. 'The only valid practical criterion,' as I have already said, (Proc. Ent. Soc. Phil. II, page 220) of specific distinctnes is the general non-existence, either actually ascertained or analogically inferred, of intermediate grades in the distinctive characters, whence we may reasonably conclude that the two supposed species are distinct, i.e., that they do not now, in general, mix sexually together, or if geographically separated, that they would not do so, supposing them to be placed in juxtaposition."

He substantiates these statements by many careful observations in nature as well as by experiments on several species. In this connection he says,

"Hence, we may conclude, first, that *tessellaris* may, without very material injury to its health, be shifted on to Oak from other trees on which it naturally feeds: for although, of those that were retained on oak, a much larger percentage spun up than of those that were shifted on to oak from other trees, yet a considerable percentage of the former, and none whatever of the latter died in confinement. Second, that sycamore is not a congenial food for *tessellaries;* for a considerable percentage of those fed on sycamore died in confinement, and a small percentage spun up. Third, that oak is adhorrent to *Harrisii* as a food plant. It may seem strange at the first view, that *tessellaris* can be compelled to feed upon sycamore up to the time of its assuming the pupa state, and *Harrisii* cannot be compelled to feed for any length of time upon oak; but when we consider that in a state of nature the former is polyphagous and the latter monophagous, our surprise will cease. It is not that *Harrisii* does not eat the oak leaves furnished to it—for the quantity of excrement on the floor of the breeding-cage at each shifting and cleaning out proved that it must eat them—but that having eaten them, it either perishes of disease superinduced by the unnatural food, or bores its way out in despair through the millinet of the cage, or devours its own brethren in default of its natural food-plant."

More than 50 years later while working without knowledge of Walsh's investigation or conclusions, Craighead found that some species of wood boring beetles acted very much as those mentioned above. Of *Cyllene pictus* he writes (5),

"The larvæ of *Cyllene pictus* feed almost exclusively in hickory. A few specimens have been taken in wild grapevine (*Vitis sp.*), mulberry

(*Morus rubra Linn*), osage orange (*Toxylon pomiferum Raf.*) and hackberry (*Celtis occidentalis Linn.*), but such instances are rare and of very local occurence. In one locality near Harrisburg, Pa., all except one of these unusual food plants have been recorded. This borer is found generally distributed east of the Mississippi River."

After describing several experiments with this insect on host selection and adaption he concluded that "This species, although most commonly found in hickory, will readily adapt itself to several other plants, notably mulberry and grape, both of which are recorded as natural hosts.

"In some unfavorable hosts, or in an optimum host in an unfavorable condition, the larvæ may become established, but the mortality is high and the progeny seem to be sterile."

"*Neoclytus capraea*," he says, "is known to inhabit the eastern and central western United States, extending its range south and west into Arizona. It has been recorded from only two hosts, ash (*Fraxinus*) and white oak (*Quercus alba* of the Rocky Mountains). In the eastern United States it has never been found in oak." This is followed by observations of this insect's habits in nature as well as by descriptions of several carefully executed experiments after which he concludes, "The foregoing experiments show that this species feeding in ash (*Fraxinus*) has become decidedly accustomed to that host.

Several attempts, both by oviposition and larval transfers, to produce strains in *Quercus alba* Linn. and *Hicoria* have resulted in failure. In *Hicoria* the few adults secured were incapable of continuing the colony, and in both woods a high or total mortality occurred.

"Even with this decided preference for a host, the adults laid eggs on a new host rather than on an unfavorable cut of the normal host."

Speaking of *Molorchus bimaculatus* he says, "a very decided predilection for the orignal host is exhibited by the host strains of this species. It is not surprising in the case of the hackberry form, as this is the only host from which it has been found. However, this form would not even lay eggs on any host other than the orignal."

On page 411, Volume III, Walsh (3) writes as follows: "That there may be no mistake, it may be as well to say here that the difference between what I call a Phytophagic Variety and what I call a Phytophagic Species is simply this: The former habitually intercross with the normal race, and the latter do not."

Craighead noted the fact that several species in his experiments, after having bred in the same wood two or three years did not copulate as readily with other strains as did those from the same plant.

After years of careful experimenting with certain cerambycid beetles Craighead (5) summarizes his results as follows:

1. In practically all the species experimented with the adults show a marked predilection for the host in which they have fed as larvæ, provided they are not deterred by other factors, such as the unfavorable condition or the small quatnity of the host.

2. There is considerable variation in the degree of preference for the orignal host, as between different species. Thus—

    . (a) Certain species are capable of living in only one genus or species of plant, which consequently they select.

    (b) Certain species, chiefly those living in nature in several hosts, can be forced to adopt a new host.

    (c) Certain species, chiefly those feeding in nature in a great variety of plants, show little discrimination in the selection of hosts.

    (d) Certain species feeding in nature in a great variety of hosts often show preference for a few of these.
3. In forced transference of individual adults of a species to a new host, a high mortality of the brood usually occurs, especially in the case of eggs laid by beetles emerging from the original host, in which case the mortality is often total. One-half to full-grown larvæ, however, usually can be successfully transferred to a new host and live and transform to adults.
4. With some species that can be reared in a secondary (new) host, by the larvæ feeding one or part of one year, preference for that host is shown by the resulting adults.
5. In general, the fewer the hosts in nature, the more marked the predilection for a particular host and vice versa.
6. Continued breeding in a given host intensifies the preference for that host.
7. The condition of the host has a great influence on host selection, in that every species prefers an optimum condition of the host which it selects and will choose a new host in the optimum condition in preference to an old host in which conditions are unfavorable.
8. The quantity of wood at the disposal of the ovipositing adults may influence the insects in their choice between different kinds of host wood, in that, if there are many adults to a limited amount of the primary host, some species will select a secondary host if such is available. If this is done, however, the resulting brood is weakened.

"It is altogether possible that these experiments may indicate the origin of certain closely related species or varieties of insects. For instance, a species restricted to a very few plants may accidentally be forced to take a new host (as actually happened in the experiments with Cyllene in oak). A few individuals may survive and continue the strain so that it becomes after a time, at least physiologically different and may also develop correlated differences of colors or structure. It can hardly be said that such forms are much less distinct than in the case of the two species *Callidium antennatum* in pine and *C. janthinum* in juniper; for even though these have a slight color distinction and each is absolutely restricted to its own host, they interbreed. On the other hand, in the different forms of *Hylotrupes ligneus*, of which the eastern form in juniper is constant in marking, the western form in redwood is quite variable, as is also the Rocky Mountain form in Douglas fir. The juniper and redwood forms interbreed, but all attempts to mate either of these with the Douglas fir form have failed. All these forms can be furnished with substitute hosts, but in the experiments in which this has been done the orignal color pattern has resulted thus far.

"The grape and hickory strains of *Cyllene pictus*, although showing no color differences, do not readily mate. Two species of Cyllene, *C. Pictus and C. robinae*, are separable only as adults, by a slight difference in the color pattern, yet in seasonal and biological habits they are strikingly different. It is conceivable that one of the two species originated through the adoption of a new plant and continuous breeding in that plant.

"It may be asked, If one or two years' feeding in a new host results in individuals which prefer that host, thus giving rise at least to new physiological varieties, why does not this occur more frequently in nature? That it does occur must be granted, as we have species living in many host plants as well as those restricted to a species or genus, but that it is not of common occurence is believed to be due to the high mortality in first-stage larvæ in a new host rather than to absence of oviposition in the new host. Although the adults show decided predilection for a favored host in oviposition and even, in certain species, a preference for the plants in which the larvæ have fed for one or two generations, the instinct to oviposit seems to overbalance that of host selection, consequently new hosts are frequently selected—possibly more frequently in nature than is generally realized. As an example of this, take *Cyllene pictus*, requiring hickory cut during the winter. This condition would be fully met in tops left during logging operations. When the timber cutting ceased, a concentration of adults would be left with none of the favored host plant available in the right condition. The grape, osage orange and hackberry strains collected at Hummelstown, Pa., were in reality taken in woods which had been logged for hickory and in which operations had ceased three years prior to the finding of these strains. At Falls Church, Va., in June 1920, adults of *Neoclytus erythroceaphalus* were observed on pine logs. Much infested ash, from the previous year, was lying about from which they had emerged in great numbers."

Bellyea (6) after experimenting on the control of White Pine Weevils, *Pissodes strobi*, by the use of mixed plantings of white pine and Scotch pine concludes that "The use of Scotch pine with white pine in mixed plantings under the conditions described in this article has reduced the amount of infestation in the white pine by almost 40 percent." Under the conditions of his experiments as reported this weevil breeding in a natural growth of white pine, infested the new plantation of Scotch pine more readily than the new plantations of white pine. This together with other data which he gives, indicates that this insect was influenced, in its choice of plants upon which to oviposit, as much or more by other factors, than by the inherited tendency to breed in its natural or original host.

Pictet (7) has shown by several examples that caterpillars of the second and third generation may be made to change their preferred food plants and that the adults reared from them exhibit changes in size and coloration. Corresponding observations were made by Schroder (8) who in a previous article (9) had showed "that even nidification (in *Gracilaria stigmatella F.*) and habits of feeding, combined with changes in reproduction (in the beetle *Phratora vitellinoe L.*) can be changed and that these acquired characters are transmitted spontaneously from the third generation."

In 1907 and 1908 Marchal (10) succeeded in transferring (5) numerous specimens of *Lecanium corni* Bouche from the peach (*Amygdalus persica* Linn.) to the black locust (*Robinia pseudacacia* Linn.). Eggs hatched and larvæ developed on the new host plant, spreading out over the leaves in large numbers, and in the fall migrating from the leaves of the wood for hibernation. In the summer of 1908 the insects completed their development and had then the large size, deep coloration, and characteristic appearance of the insect described by Douglas as *L. robiniarum*, the attack of which on the black locust had been severe in several European localities. This indicated that *L. robiniarum* was only a race of *L. corni*, resulting from individuals that had become transferred in some manner from the peach to the introduced American black locust. Dr. Marchal found great difficulty in reestablishing on the peach individuals of *L. corni* produced on the black locust.

With reference to the adaptability of certain lepidopterous larvæ, Dr. Brues (11) writes as follows:

> "It has been claimed that the food habits may be modified experimentally, in that caterpillars reared on a strange plant (where they could be induced to select it) gives rise to moths whose progeny more readily accept the new plant. It is very difficult to accept such evidence, at least as having any general application, without very clear and incontrovertible proof. If such transformations can occur so easily and become hereditary so quickly they would have entirely destroyed the coherent habits now existent, during the enormous period which has elapsed, for example, since the violet-feeding Argynnids were differentiated, since the holarctic and nearctic Vanessids have been separated, or while the world-wide Aristolochia feeding Papilio were attaining their present distribution. That such a change has actually occurred in the case of other groups seems equally evident, although, as has been shown, we can more easily believe that they may have arisen through mutations in maternal instinct not incompatible with larval tastes and then only in extremely rare cases and confined to certain groups."

That the host selection principle is operating with Anopheles mosquitoes is claimed by certain writers. E. Roubaud (12-13)* points out that *A. maculipennis*, the chief malaria carrier of northern and central Europe, has come to prefer domestic animals to man; it has become "zoophilic" even to the extent of a change in the maxillary dentition; and this change in the blood-seeking habits of the *Anopheles* has been a large, if not the chief factor in the diminution or disappearance of malaria from certain well-populated regions of Europe, even in the presence of an adequate number of *Anopheles*.

In his "Mosquito Observations in Different Countries During the Past Three Years," Dr. Howard (14) says:

> "Wesenberg Lund (15), in 1921, published a very important paper on the biology of the mosquitoes of Denmark, and thinks that the change pointed out by Roubaud has occurred in the last century; that formerly this malarial mosquito was mainly dependent upon human blood and that it has become almost exclusively an attacker of domestic animals, especially pigs, over most of Europe north of the Alps."

He also shows that various writers in Germany, Spain, Algeria, Albania, Sumatra and elsewhere have become convinced that domestic animals have been very prominent factors in protecting people from the ravages of malarial mosquitoes. The inference by at least part of these writers, is that the mosquitoes are changing their habits.

On this phase of mosquito activity, Barbar and Hayne (16) of the United States Public Health Service write the following:

> "Our observations indicate that of the *Anopheles* mosquitoes common in this country, *A. qudarimaculatus* and *A. crucians*, at least show no special predilection for domestic animals over man when such factors as size and amount of exposure are excluded. The conditions which Roubaud describes as obtaining in France are not present in this country, at all events not in the Southern States. In the milder climate of these States many domestic animals roam at large in pastures night and day, summer and winter; stables are often of an airy construction and are rarely built immediately adjacent to human dwellings. Domestic animals may act as "buffers" in that they satisfy mosquitoes that otherwise might have fed on man, but there is little evidence that the *Anopheles* of this country have become zoophilic in the sense of Roubaud, or that they are likely to become so. It is questionable

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*The structural change is open to verification and recent papers by Sergent and by Shannon cast doubt upon Roubaud's conclusions, which by the way, have been critised by Martin and others. (See L. O. Howard's paper on "Zoophilism with Anopheles," Journal Parasitology, Vol. X, pp. 191–98, 1924.

whether the increase in animal industry, apart from drainage and other concomitant improvements, has been a large factor in the decrease in malaria which has occurred in many parts of the United States. It is unlikely that a cordon of stables could afford much mosquito protection to dwellings, even if such a cordon could be maintained.

> "So far as the results of one experiment indicate, one would not expect that a feeding on a domestic animal would affect the subsequent susceptibility of *Anopheles* to malaria parasites."

The sugar beet nematode *Heterodera schachti*, according to Capus and Marchal (17) may become adapted to other plants to the exclusion of their chief food plant. They say:

> "That, by virtue of the conditions of pea culture in the Gironde, a race of *Heterodera schachti* was found especially adapted to peas and to the attack of which beets are resistant up to a certain point."

This is substantiated by other writers.

Nillson-Ehle, (18) writing of experiments conducted in southern Sweden on the resistance of certain barley varieties to *Heterodera schachti* says:

> "Another consideration is the fact that *Heterodera Schachtii* also attacks sugar beets and other crops. Beets were never attacked by the barley strain of the organism, indicating biological strains of the organism, showing preference for particular hosts. It is probable that both strains occur together in the soil, and that if a crop of one host is grown in successive years, its particular strain will multiply. This explains the increase in infection in successive years after a crop of the other host. Another possibility is that there is a strain capable of attacking both hosts."

Thorne (19) in the U. S. Bureau of Plant Industry, writing of this same species, says;

> "My own observations on *H. schachtii* lead me to believe that there is a ready change made from certain weeds, notably mustards, *Chenopodium* and *Atriplex* to sugar beets. Of this I am reasonably certain since fields which have been out of beets for 10-14 years have been reinfested the first year beets were again planted. However, I do not doubt that certain strains do become rather permanently adapted to certain crops."

Other records show the acquired adaption of certain species to new host plants. The practical application of such phenomena in economic work, apparently, has first been recognized by Dr. A. D. Hopkins (5) who made use of it in control operations conducted against the moutain pine beetle *Dendroctonus monticolae* Hopk. attacking areas of yellow pine (*Pinus ponderose*) along the Pacific Slope.

GENERAL APPLICATION OF THE PRINCIPLE.

In a letter (20) to the writer, Dr. Hopkins says, "I feel confident that this principle will be found to have a broad application in economic entomology but we must expect to find some striking exceptions which, however, if not too numerous may prove the rule."

If this principle is found to have a wide application in entomology it will probably be found to be applicable to other branches of zoology. Many problems in parasitology may possibly be solved more readily in the light of the host-selection principle. It may even assist in solving problems of racial and individual immunity as well as the formation of new species.

Before this principle can be termed a rule in economic entomology very much more work will have to be done with many species of insects having widely differing life histories. A principle that applies to certain wood boring beetles and leaf eating caterpillars may not apply to certain other groups such as leaf hoppers and insects attacking stored products.

Some insects are known to feed in nature on a great variety of host plants while others are restricted to relatively few hosts. Experiments conducted at the Gipsy Moth Laboratory (21) show that of the many plants tested a decided variation was found in regard to the susceptibility to attack by this insect *Porthetria dispar*. The plants were divided into four groups; I, favored species; II, favored food species after early stages; III, species on which a small proportion may develop; IV, species that are unfavored food. These results show that, although this insect has a wide variety of hosts on which it is capable of feeding, certain ones are selected in preference to others in the natural forests. Just as great variation undoubtedly exists with some other miscellaneous feeders. It is conceivable even, that certain species may be held in check to a great extent by the choice of unfavorable hosts for oviposition, or the selection by the young stages, of hosts which are unfavorable for later development.

The codling moth, *Carpocapsa pomonella*, in nature has been restricted to comparatively few hosts. When it was first found to be working in English walnuts, *Juglans regia*, it was thought to be another species. However, numerous observations have shown that the moth lays its eggs rather promiscuously on a great variety of plants as well as on various parts of the plants. Professor Quayle, (22) whose extensive experiments with this insect have not been published, says:

> "The codling moths that were reared from the apple oviposited equally freely on walnut and apple, as well as on pear and some other fruits that were in the same cage. Codling moths from the walnut also oviposited equally freely on the same fruits, apparently showing no discrimination. In the case of the walnut tree covered with cheese cloth the same facts were true, excepting that the larvæ upon hatching showed some preference for the apple over the walnut, that is, some of the larvæ that hatched from eggs on the walnut made their way over to the apple which they entered.
>
> "In other words, so far as my experience goes, there was no indication of different species or varieties but that their habits were identical whether bred from the apple or from the walnut."

While the larvæ of the codling moth show some preference for apples it seems that this tendency is not transmitted to the adult neither does it appear that breeding in one host has any influence in causing the choice of that host for oviposition. It is probable that the larvæ are able to penetrate the apple with greater ease or that the apple offers greater protection while effecting their entrance. In an orchard where apple and walnut trees alternate this slight preference would be of no importance because it would be practically impossible for the young larvæ on the walnut trees to reach the apple trees therefore in an orchard of this kind the only possible selection would be made by the adult. Copulation appears to occur as freely between insects having bred in different hosts as with insects having bred in the same host. So far as present knowledge goes, there is no indication that the host selection principle will hold with the codling moth.

Work with the Hessian fly, *Phytophaga destructor* indicates that with an abundance of food available it will breed on several plants with preference shown for certain plants (23). While sufficient data has not been accumulated to justify a definite conclusion, it appears probable that resistant varieties of grain may be developed, and that "strains" of Hessian fly breeding on single species of plants do not develop.

If there is any large group of insects in which this principle will not hold, it will undoubtedly be with those injuring stored products. Among these may be included some species of lepidoptera and many species of coleoptera. Although the writer has no tabulated data, his work with bean weevils, has called him into warehouses throughout California and other states and has given him an opportunity to observe these insects under varying conditions.

The rice weevil, *Calendra oryza*, which in India was a pest in rice, breeds freely in the United States in wheat, corn, oats, barley, sorgum, kafir, buckwheat, rice and sometimes in flour and meal if they become caked. The writer's observations indicate that this insect does not produce "strains" or "phytophagic species" but that copulation takes place freely between individuals having bred in different hosts. In mixed grains such as some of the scratch feeds for poultry this insect appears to work indiscriminately generation after generation.

In speaking of the Indian Meal Moth *Plodia interpunctella*, Dean (24) says,

> "This insect feeds on edibles of almost every sort, such as meal, bran, flour, grain, breakfast foods, dried fruits, roots, seeds, nuts, etc. It will attack dried insects, herbariums and other museum specimens. It has even been taken in bee hives, where it was working upon the comb, or wax."

The writer's observations on this insect indicate that it shows no tendency towards the development of strains manifesting a preference for the host from which they bred.

Numerous other insects of economic importance in this group might be cited whose tendencies do not point toward the development of new species by way of the host-selection principle, but rather point towards a wider range of materials upon which to perpetuate the species.

An interesting example of an insect of no apparent economic importance adapting itself voluntarily to new conditions thus making it a potential menace has been observed by the writer. The insect *Bruchus pruninus* has been known for years to breed only in acacia seeds. During the summer of 1920 the writer grew beans of different varieties near some acacia trees, *Acacia melanoxylon*, in which the seeds were infested with this weevil *B. pruninus*. After harvesting the beans they were kept for observation in connection with the work on *Bruchus obtectus*. From some California pink beans a few very small weevils emerged. At first they were thought to be *B. obtectus* which had failed to develop normally in size and color but when several of them emerged they were determined by J. C.

Bridwell as *B. pruninus.* In 1921, the writer grew another crop of beans in another locality near the same species of acacia trees. That year *B. pruninus* emerged from soy beans, *Glycine hispida*, red Mexican, California Pink, and Early Refugee beans, *Phaseolus vulgaris.* In neither of these cases was the insect forced, because of scarcity of food or because of the food being in an unfavorable condition to oviposit on the cultivated plants. The writer bred them in the soy beans in storage four generations. After four generations they were killed by mites, *Pediculoides ventricosus*, before the writer had an opportunity to determine whether or not they showed any predilection for soy beans or for acacia or whether they would mate freely with those breeding in acacia seeds but as far as his observations went there was no difference in size or color.

As there are many varieties of beans grown in California near acacia trees, which as far as the writer has observed are infested with this weevil, it would be very likely that every year some beans become infested with this weevil. It would also seem quite probable that if it inherited tendencies in accordance with those presupposed in the host selection principle, it would have developed a strain of weevils living only in beans of the same variety and that it would have attained some economic importance. The writer however, has been unable to find that any one else has even observed it breeding in beans.

It appears that in nature this insect oviposits on new hosts even in the presence of abundant material of the normal host or the host in which it had bred. It also seems that weevils emerging from new hosts do not become established thereon, but return to the primary or original host.

EXPERIMENTS AND OBSERVATIONS ON *Bruchus quadrimaculatus* Fab.

Bruchus quadrimaculatus Fab. is found wherever cowpeas are grown extensively. Because of the great damage it does to the crop together with the added labor and expense it causes, its importance is very great. In some sections farmers have discontinued growing cowpeas because of the heavy loss due to the ravages of this insect. Frequently the entire crop, which at the time of storing shows no apparent weevil injury, in a short time is a total loss. With blackeyed cowpeas and probably with other varieties this loss is caused not only by the number and amount of the seeds actually devoured but by the mold and decay, which as has also been pointed out by Chittenden (25), Swenk (26), and others, usally follows more promptly the attack of this weevil than of any other.

The following is only one of the many examples of the heavy losses caused by the four-spotted cowpea weevil, *B. quadrimaculatus*. One car load of blackeyed cowpeas, after passing inspection in Los Angeles, was shipped to Georgia. The car was less than a month in transit, but on arrival at its destination it was found to contain 300 bags so badly weevil damaged that they were a total loss.

It would be impossible to give an accurate estimate in dollars, of its injury in the United States, because not only do the production and price of cowpeas vary from year to year, but the actual weevil injury also varies from year to year.

In California its chief food is the blackeyed cowpea, but the writer's observations indicate that it thrives equally well and shows little if any preference for any variety of cowpeas, *Vigna sinensis.*

Paddock and Reinhard (27) record having bred it from the following varieties of cowpeas: blackeyed, old Bokhara, Chinese red, Chinese yellow, red ripper, iron, speckled cowder, whip-poor-will, tinkles Holstein, new era, and lady pea.

They say, speaking of *B. quadrimaculatus,* "The cowpea weevil has not been observed to feed upon any plant except the cowpea—it is doubtful if any other plants can be added to the cowpea as a food for this insect." Speaking of its adaptive capacity they say, "There is a very little flexibility in the habits of this insect to adapt itself to a strange environment. This is particularly true with respect to its food plant. Changing the food from one variety of cowpea to another did not apparently affect the weevil, but when a nearly related food plant, such as certain varieties of beans, navy, and lima, were repeatedly tried, the weevil would not complete its life cycle. In all experiments egg deposition took place readily enough, as has been elsewhere stated. The eggs hatched in a large percentage of cases, but the larvæ could not subsist in the substituted food, and all were dead within three days after hatching. In the field the cowpea weevil has not been collected consistently on any plant except cowpeas. When the food is removed the weevils probably disseminate from that point to other patches of cowpeas, instead of attacking other plants growing adjacent to infested patches. The weevil is restricted to the cowpea as a food plant."

Writing of the same insect, Pettit (28) says, "It will also feed on table beans on occasion," and later he adds (29), "It also works in the common bean and like the common bean weevil it works indefinitely in the stored seed until nothing of value is left. Like the bean weevil, this creature starts work in the field, coming into the granary with the harvested beans, or it may gain access after the beans have been stored away."

Back and Duckett (30) say, "Peas and beans of many varieties are attached."

Skaife (31) working in South Africa in 1918 reported that they "Oviposit freely on peas and beans, but I have not succeeded in rearing any in these seeds. The eggs hatch normally and the young larvæ burrow into the seeds, but they all die without attaining any size."

Bridwell (32) in Hawaii the same year, says, "I have bred it (*Bruchus quadrimaculatus*) experimentally from *Phaseolus lunatus*, *P. articulatus*, *P. aureus*, *P. acutifolius*, *Dalichos lablab*, *Vicia faba*, and *Pisum satavum*."

SCOPE OF THE EXPERIMENTS.

The above records make it quite apparent that the same results have not been obtained either naturally or experimentally in different localities. The writer, therefore, has been carrying on experiments for 5 years to determine the possible range of host plants as well as its tendencies toward the development of strains becoming adapted to certain host plants.

These experiments have been carried on at Alhambra, California. Seeds of numerous kinds as are shown in the following tables were used. Counted numbers of seeds of various kinds, sometimes alone and sometimes mixed, were placed with counted weevils of known age, in glass containers, Mason jars, or glass vials, where they could be carefully studied. Their habits and length of life were recorded as were the numbers of eggs laid on each individual seed as well as the total number of eggs on all the seeds. Hundreds of records of individual weevils and their progeny have been made. Table 1, shows a typical record of a pair of weevils and their progeny. In this instance the eggs were laid on blackeyed cowpeas. This particular record is taken because it illustrates the possibility of an infestation, which occurs at, or immediately after harvest, being carried several months without becoming apparent to the casusal observer. Had the record begun at the beginning of warm weather instead of the beginning of cold weather, the record of emergence would have been complete in from 27 to 42 days instead of from 98 to 132 days, or in other words, a generation would have been complete in a month or six weeks instead of three to four and one-third months. The table is also typical in showing little or no difference in the rate of development of males and females emerging from eggs laid on the same day. The first and last emerging weevils may be of either sex.

TABLE 1.

Record of one pair of *Bruchus quadrimaculatus* Fab. and their progeny (first generation)* showing the minimum, maximum, and average duration in days of the life cycle of all the weevils, the males and the females from each day's eggs.

Weevil Number	Date of Oviposition	Number of Eggs Oviposited	Number of Eggs Hatched	Number ♂ Emerged	Number ♀ Emerged	Total Number of Weevils Emerged	Minimum Number Days Required	Maximum Number Days Required	Average Number Days Required	♂			♀		
										Minimum	Maximum	Average	Minimum	Maximum	Average
11	9/20	21	16	8	6	14	98	130	111	100	129	114	98	130	107
....	21	11	9	1	5	6	102	132	117	132	132	132	102	127	113
....	22	13	12	6	4	10	104	126	111	104	126	111	107	115	111
....	23	12	11	4	6	10	99	117	107	99	117	107	99	117	108
....	24	12	11	5	4	9	103	124	114	104	124	113	103	123	115
....	25	7	4	1	3	4	116	126	121	121	121	121	116	126	121
....	26	14	11	4	6	10	115	127	122	118	126	122	115	127	122
....	27	1	0	......	......	......	......	......	......	......	......	......	.....	.....	......
....	28	0	......	......	......	......	......	......	......	......	......	......	.....	.....	......
....	29	1	0	......	......	......	......	......	......	......	......	......	......	......	......
...	30	1	0	......	......	......	......	......	......	......	......	......	......	...	......
Total.....		93	74	29	34	63	98	132	114	99	132	114	98	130	113

* Preoviposition period was less than 1 day. ♀ died the day of the last oviposition record.

It is impossible to say definitely how long this weevil has been in California, but the writer has examined specimens taken in widely separated sections as early as 1913. In some sections where it has caused serious losses, it has, for 10 years or longer, had only one host plant, the blackeyed cowpea. During this time at least 50 or more generations have developed in the same host.

Early in 1919 the writer having only weevils which had bred 50 or more generations in blackeyed cowpeas, placed them in containers with the following varieties of common beans, *Phaseolus vulgaris*, Mexican red, pink, Lady Washington, and blackeyed cowpeas, *Vigna sinensis*. After daily observations as to the variety of beans on which it preferred to oviposit, he concluded that with these beans its choice was in the following order; first, Mexican reds, second, pinks, third, blackeyes, and fourth, Lady Washingtons. Because of this preference for the Mexican reds and also because the eggs could be seen most easily on that variety, it was used almost entirely for making daily records of the number of eggs deposited by a series of females during their lives. As a result, eggs were laid on all varieties but principally on Mexican reds. All the eggs were put together in one container for each day. Towards the latter part of the series only Mexican reds were used. Between July 7, and 25, 5718 eggs were deposited; of these 2661 were on Mexican reds having no other variety among them. Of the other 3057 eggs, the majority were on Mexican reds. From all these eggs 358 weevils emerged from the blackeyed cowpeas. About two-thirds of the eggs on the blackeyed cowpeas produced adult weevils, while not a weevil emerged from the other varieties of beans. In the varieties other than blackeyes, the tiny larvæ usually died immediately after boring through the testa or seed coat, but in some instances they were able to make a perceptible cavity in the cotyledon before they died.

EXPERIMENTS TO DETERMINE HOST PLANTS.

In an effort to determine the possible range of host plants among the seeds available at the laboratory in 1920, several pairs of weevils were placed in vials containg the following varieties of seeds:

Large white limas *Phaseolus lunatus macrocarous.*
Henderson bush or baby limas *P. lunatus.*
Tepary *P. acutifolius.*
Scarlet runner *P. multiflorus.*
Velvet bean *Stizolobium* sp.?
Castor bean *Ricinus communis.*
Lentils *Lens esculenta.*
Soy bean *Glycine hispida.*
Yard long or asparagus bean *Doliches sosquipedalis.*
Chick pea *Cicer arietinum.*
Broad windsor *Vicia faba.*
Two varieties of cowpeas *Vigna sinensis.*
Twenty varieties of common beans *Phaseolus vulgaris.*

Eggs were deposited freely on all varieties of seeds but emergence occurred from only two varieties of cowpeas, the broad winsdor, chick peas, yard long, soy beans, and lentils. On all of the other varieties the eggs hatched normally but the larvæ died before they had wholly entered the cotyledons.

The foregoing seeds had been purchased on the market with no way of determining how old they were or whether they had been fumigated.

Experiment 2.

In order to determine whether or not the age of the beans might have some influence on the ability of the larvæ to subsist within them the following freshly harvested varieties were used and the results compared with those obtained by using the same varieties one or two years old.

1. Tepary
2. Baby lima
3. Pink
4. Small white
5. Bayo
6. Cranberry
7. Refugee Green Pod
8. Brown Kentucky Wonder
9. Mexican Red
10. Red Kidney

Numerous eggs were deposited on each sample and the same results were obtained from all these varieties, from the newly harvested beans and from the old ones. All larvæ died soon after hatching, many of them having penetrated through the seed coats of each variety.

Experiment 3.

That the young larvæ might more easily penetrate the beans the following varieties were tried after being moistened as well as in their dry condition.

1. Baby limas
2. Teparys
3. Pinks
4. Navy
5. Pinto
6. Bayo
7. Cranberrys
8. Brown Kentucky Wonder
9. Refugee Green Pod
10. Mexican Red
11. Red Kidney

Oviposition took place as freely on the dry as on the moist beans. The eggs hatched normally in each case but the larvæ died before penetrating to any depth, although it is generally conceded by entomologists, bean-growers, and dealers alike, that moist beans furnish ideal conditions for the development of weevils.

Experiment 4.

Weevils were allowed to oviposit on the following varieties of beans after all of their seed coats had been removed except a small area which was left for identification.

1. Limas
2. Baby limas
3. Pink
4. Small white
5. Large white
6. Bayo
7. Cranberrys
8. Brown Kentucky Wonder
9. Refugee Green Pod
10. Tepary
11. Red Kidney
12. Mexican Red

Eggs appeared to be laid as freely on one part of the beans as on any other, they also hatched as well on one part as on another, but in no case did the larva enter the bean more than a short distance before it died.

The above experiments seemed to indicate that under local conditions at least, this weevil was unable to develop in the following: *Phaseolus lunatus P. acutifolius, P. Lunatus macrocarpus, P. multiflorous, P. Vulgaris,* (twenty different varieties), *Stizolobium sp? Ricinus communis.*

These experiments indicate that, the age of the bean, the moisture content, and the thickness of the testa, are not prohibitive factors in the development of the larvæ. They show that the minute larvæ can penetrate into the cotyledons of any of these beans, even those having such thick hard coverings as that of the lima, Italys Favorite, the velvet bean, the broad windsor or horse bean, or even the castor bean. Figure 1 shows (a) eggs on horse bean (b) eggs removed to show entrance holes, (c) seed coat removed to show the depth of penetration. The weevil can breed in this bean.

The ability of the tiny larvæ to penetrate to their food is further emphasized by the fact that they can readily bore into painted lead pencils and varnished handles of disecting needles. They have made appreciable cavities in the black paint or enamel on an iron ring stand where the eggs had been deposited in the laboratory. Figure 2 shows eggs of *Bruchus quadrimaculatus* on lead pencils (Dixons No. 3 and No. 6 H) and the varnished handle of a dissecting needle also the depth to which some of the larvæ burrowed.

At Tucson the Plant Breeding and Agronomy Department of the University of Arizona, had a great many varieties of seeds in a store room where weevils had access to the various seeds. These were contained in laboratory jars and sacks and had been fumigated, but had been reinfested. Some of the jars contained stoppers while others did not. There was evidence to indicate that weevils had had access to almost all of the seeds at some time. While the Angoumois grain moth and some of the grain weevils were present, the insect most in evidence and the only Bruchid observed was *B. quadrimaculatus*.

I examined those seeds very carefully, and dissected many of each variety where eggs of *B. quadrimaculatus* were present. The following list gives the varieties of seeds and the number of samples of each variety in which I found the above weevils breeding:

Warshaver field peas *Pisum sativum* (2 samples),
Colorado stock peas,
Early Ramshorn blackeyed cowpeas *Vigna sinensis*,
Blackeyed cowpeas,
Black cowpeas,
Wonderful or Unknown cowpeas,
Whip-poor-will Cowpeas (4 samples),
Brabham cowpeas (2 samples),
Peking cowpeas,
White Crowder Cowpeas,
New Era Cowpeas,
Garbanza or Chick Pea *Cicer arietinum* (2 samples),
Bitter vetch *Vicia ervilia*,
Bitter vetch (Different strain),
Tarheel Black Soy *Glycine hispida*.

The two samples of bitter vetch appeared to be of two different strains, and while the emerging weevils were not numerous in the one sample, they were hard to find in the other. Both samples were well covered with eggs. The Tarheel Black soy beans were also well sprinkled with eggs but I found only three emergence holes, a few young larvæ which had died after entering well into the cotyledons, and one well developed weevil. Continued dissection undoubtedly would have revealed more of the insects.

The following is a list of unprotected seeds upon which I found the eggs of *B. quadrimaculatus* but from which no weevils had emerged.

Red Valentine beans *Phaseolus vulgaris*
Brown Kentucky Wonder Beans
Lady Washington Beans (3 samples)
Prolific Black Wax Beans
Improved Golden Wax Beans
Pinto Beans
Colorado Pinto Beans
Hansen Yellow Beans
Bates Beans
California Pink Beans
Dwarf Spanish Beans
Tepary Beans *P. acutifolius* (3 samples)
Unknown soy beans *Glycine hispida*
Tokio soy beans
Virginia soy beans (2 samples)
O-too-tan soy beans
Moqiu lima *P. lunatus* (2 samples)
Mung Beans *P. aureus*
Rice bean *Phaseolus calcaratus*
Scarlet runner bean *P. multiflorus*
Scarlet vetch *Vicia fulgens* (2 samples)
Vetch *V. monantha* (2 samples)
Wooly podded vetch *V. dasycarpa*
Purple vetch *V. atropurpurae*
Vetch *V. villosa*
Vetch *V. sativa*
Vetch *V. angustifolia*
Corn, Hickory King, *Zea mays*

Corn, Bloody Butcher
Corn, several kinds of Indian corn
Honey Drip sorghum *Andropogon sorgum*
White Kaffir corn
Speltz, *Triticum stacium spelta*
Burbank Superior Wheat *Tr. sat. vulgars*
Kanred Wheat
Turkey Red Wheat
Velvet beans *Stizolobium sp.*? (2 samples)
Chinese White Velvet Beans *Stizolobium* sp.?
Early Bird Velvet Beans *Stizolobium* sp.?
California Red Oats *Avena stavia*
Egyptian cotton
Common Buckwheat *Fagopyrum esculentum* (2 samples)
Japanese Buckwheat *Fagopyrum* sp.?

In every variety of the above seeds except the Egyptian cotton the young larvæ bored through the seed coat before dying. Although the eggs were fairly numerous on the Egyptian cotton seeds, I was unable to find where a single larva had penetrated to the cotyledon. This I concluded was because the eggs were not firmly attached to the seed coat. The fibers to which each egg was attached allowed the chorion to move, thus preventing the larva from obtaining proper support for drilling.

The following is a list of freely exposed seeds upon which I found no eggs of *Bruchus quadrimaculatus.*

Feterita,
Kidney vetch,
Broom Corn,
Alfalfa; different samples of different strains,
White Sweet Clover,
Yellow Sweet Clover,
Kale,
Several kinds of grasses.

The seeds of the feterita and broom corn are small and quite pubescent. It would seem probable that in these cases it was the pubescence and not alone the size of the seeds which prevented oviposition but with the remainder of the seeds in the above list the size appears to be the prohibitive factor.

Observations made in the numerous warehouses of California together with those in other states, indicate that this weevil will oviposit on a great variety of seeds even when its chief hosts are abundant, also that it is unable to develop in any of the following varieties of beans: *P. vulgaris*, *P. lunatus macrocarpus*, *P. lunatus*, *P. acutifolius*, *P multiflorus*, *Stizolobium* sp?.

These observations have been corroborated by extensive experiments in the laboratory. More experiments along this line will be given in connection with the choice of varieties upon which to oviposit.

HOST-SELECTION SHOWN BY PREFERENCE FOR OVIPOSITION OF *B. quadrimaculatus.*

Experiment 5.

Ten varieties of common beans were selected and 5 of each variety were placed in Mason jar with a few pairs of *B. quadrimaculatus.* When the weevils were removed it was found that oviposition had occurred as indicated in Table 2, first trial. This was repeated 3 more times using old beans in trials 1, 2, and 4, and freshly harvested beans in trial 3.

TABLE 2.

Preference for Oviposition of *B. quadrimaculatus* on Ten Varieties of Common Beans.

Variety of Beans	1st Trial, Old Beans	2nd Trial, Old Beans	3rd Trial, Newly Harvested Beans	4th Trial, Old Beans	Total
Bayo	39	36	24	32	131
Cranberry	28	30	21	29	108
Baby Lima	22	22	47	14	105
Kentucky Wonder	19	25	22	28	94
Red Kidney	17	20	44	17	98
Pink	17	16	30	18	81
Refugee Green Pod	15	16	23	28	82
Mexican Red	13	15	29	7	64
Small White	13	13	31	12	69
Teparies	1	7	10	8	26
Total	184	200	281	193	858

Oviposition was permitted to continue in trials 2, 3, and 4 until the number of eggs appeared to approximate the count of trial 1. The object in the later trials was not to obtain equal numbers of eggs but rather to see if the numbers of eggs oviposited on the different varieties would hold approximately the same ratios. The red kidneys and teparies in 1, 2, and 4 had been fumigated with carbon disulphide but no evidence of this was noticable. The Bayos, Cranberries, and Kentucky Wonders used in 3 were not well matured. As this weevil prefers to oviposit on well matured seeds, this may account for the difference in choice between these and other varieties in this trial as indicated by comparing trial 3 with either of the others. While the total number of eggs laid in trial 3 was greater than in either of the others the numbers laid on the three immature varieties were relatively smaller than in the other trials. In each of the 4 trials there was a very decided preference for certain seeds. As the Bayos were smaller than the Cranberries, Baby Limas, Kentucky Wonders, and Red Kidneys it was evident that the number of eggs on each variety was not in proportion to the amount of surface exposed. There was no emergence from any of these seeds.

Experiment 6.

Thirty-five varieties of peas and beans were selected which differed from each other in color, shape, and size sufficiently to admit their being readily separated. Five perfect seeds of each variety were placed in each of 8 one-quart Mason jars. Into jar No. 1, were placed 2 females and 3 males which had bred in broad windsor beans 2 generations. Nine females and 8 males having bred 3 generations in dwarf sugar peas were placed in jar No. 2. The 41 females and 36 males placed in jar No. 3, had bred 2 generations in prizetaker peas. Into jar No. 4 were placed 52 females and 23 males which had bred 2 generations in blackeyed cowpeas. The 12 females and 10 males, the 11 females and 8 males, 9 females and 7 males, the 7 females and 11 males placed into jars 5, 6, 7, and 8 respectively had bred 8 generations in red ripper cowpeas. Table 3 shows a very nearly uniform preference for oviposition by all these groups of weevils. The jars were laid side by side on a shelf so that the seeds were thoroughly mixed and well exposed. A total of 7692 eggs were laid on the seeds and a few were laid on the jars. Table 3 shows that all of these weevils made practically the same relative choice of seeds for oviposition. In each colum one line (—) alongside of a number indicates that was the number laid on the host from which those were bred. Two lines (=) point out the variety on which they laid the maximum number of eggs.

Figure 3 gives the comparative size of the seeds used in the above experiment. It shows that the weevils were not crowded nearly as much as they frequently are in warehouses. The largest variety of seeds received only about one per cent of the eggs or a number exceeding that on only four of the thirty-five varieties. The seeds are arranged in the ascending order with reference to the number of eggs oviposited on them in the eight jars.

TABLE 3.

Showing the Varieties of Beans upon which *B. quadrimaculatus* Prefers to Oviposit. August, 1922.

Eggs Laid by	2♀3♂	9♀8♂	41♀36♂	52♀23♂	12♀10♂	11♀8♂	9♀7♂	7♀11♂	
Variety of Seeds	Bred from Broad Windsor, 2nd Generation	Bred from Dwarf Sugars, 3rd Generation	Bred from Prizetaker Pea, 2nd Generation	Bred from Blackeyed Cowpeas, 2nd Generation	Bred from Red Ripper Cowpeas, 8th Generation	Bred from Red Ripper Cowpeas, 8th Generation	Bred from Red Ripper Cowpeas, 8th Generation	Bred from Red Ripper Cowpeas, 8th Generation	Total
Garbanza or Chick Pea...	0	0	0	3	2	1	0	0	6
Lentils....................	0	0	8	3*	0	1	0	0	12
Prizetaker Pea...........	0	0	23—	6	3	0	5	0	37
Dwarf Sugar Pea.	0	5—	26	19	12	9	10	2	83
Broad Windsor...........	0—	0	32	26	12	13	8	2	93
Mammoth Yellow Soy.. .	0	5	32	27	20	10	15	11	120
Phaseolus vulgaris (unknown).............	0	5	34	38	21	12	15	8	133
Nicaragua................	0	10	38	40	21	11	17	8	145
Black Valentine..........	0	7	40	35	25	18	21	10	156
Small Windsor...........	0	0	48	53	15	19	14	9	158
Pink......................	0	6	42	49	25	17	21	8	168
Burpee's Stringless Greenpod..............	0	4	36	59	28	19	20	14	180
Baldwin Wonder Wax.....	0	7	53	47	27	18	18	12	182
Eastern Cornfield.........	1	6	37	85*	19	14	13	13	188
Pinto......................	0	9	43	55	22	23	22	18	192
Velvet....................	0	2	59	61	38	16	19	5	200
Improved Long Yellow, 6 Weeks................	1	10	50	54	30	23	21	13	202
Blackeyed Cowpeas.......	2	5	44	60—	24	27	30	16	208
Mexican Red.............	0	11	51	49	26	25	26	24	212
Kentucky Wonder Wax....	1	3	50	65	34	24	25	14	216
Red Valentine....	0	10	54	61	30	26	20	15	216
Holstein Cowpeas.........	5	16	51	49	32	21	22	26	222
Brown Kentucky Wonders	5	11	51	64	29	24	25	18	227
Lazy Wife................	1	8	60	67	37	27	23	19	242
Cranberry................	0	12	57	60	27	32	28	17	243
Dutch Caseknife..........	2	11	69	61	33	31	22	18	247
Red Ripper Cowpea.......	6	22	59	55	35—	32—	20—	28—	257
Early Mohawk............	0	11	70	86	38	24	28	17	274
Italy's Favorite.....	1	14	71	78	40	26	27	27	284
Bayos...	4	18	77	79	43	34	27	25	307
Red Kidneys............	2	22	80	87	43	35	30	32	331
Scarlet Summer...........	3	12	99	100	54	50	56	42	416
Improved Golden Wax....	9=	25=	88	99	63	53	40	50=	427
Bush Lima	2	5	131	129	58	57	40	31	453
Ford Hook Lima.........	8	17	155=	173=	97=	92=	63=	50=	655
Total.................	58	309	1918	2092	1061	866	791	602	7692

* 10 instead of 5 seeds in this variety.

EMERGENCE FROM THE 7692 EGGS LAID IN EXPERIMENT 6.

Emergence from the eggs laid by weevils of the second generation from the broad windsor beans and third generation from dwarf sugar peas (table 3, colums 1 and 2) was confined to the cowpea only. Eggs from the second generation from prizetaker pea (column 3) produced adults in the prizetaker pea, dwarf sugar pea, mammoth yellow soy, small winsdor and the cowpeas. Eggs laid by the weevils having been bred in blackeyed cowpeas developed into adult weevils in the garbanza, prizetaker pea, broad and small winsdor, mammoth yellow soy, as well as the cowpeas. Eggs laid in the last 4 jars by weevils having been bred 8 generations in red ripper cowpeas, produced adult weevils in broad, and small winsdor, prizetaker peas, dwarf sugar peas, garbanza and in the cowpeas.

It is interesting to note that from the 35 varieties of seeds of 11 species of plants the weevils were able to develop in only 10 varieties from 7 species and that 6 of these varieties and species were at the bottom of the list in total number of eggs oviposited thereon. Although the seeds were all in good condition the ford hook lima in which the weevil was unable to develop received more than 100 times as many eggs as did the garbanza in which it breeds freely in the absence of other hosts.

Numerous experiments and observations indicate that this weevil breeds freely in the garbanza or chick pea as well as in the prizetaker pea and the dwarf sugar pea when no other host is available. It prefers to oviposit on other hosts such as the bayo and other varieties of *P. vulgaris* when available, although the larvæ are unable to develop in these varieties. In the lentils, broad windsors, and soy beans the weevils breed less freely than in the peas. This is due in the case of the lentils and broad windsors to a high mortality in the young larval and pupal stages as well as to the natural tendency on the part of the adult to avoid ovipositing thereon. The weevils oviposit more freely on the soy beans and there is a lower mortality with the young larvæ but a much higher mortality with second and the older larval stages. In some varieties of soy beans the larval development is so retarded under favorable temperature that at least twice the normal time is required and the emerging weevils are quite small. In these soy beans, the writer has been unable to get more than 3 generations to develop. This indicates a tendency towards sterility or at least an increasing lack of adaptability such as would be required by the host selection principle.

OTHER EXPERIMENTS IN 1922 ON THE CHOICE OF SEEDS FOR OVIPOSITION.

In experiments 7, 8, 9, and 10 seeds were used which were quite similar to some of those used in experiment 6. For convenience in separating them to count the eggs on each variety, only seeds which were easily separated were placed in the same container. In these 4 experiments 23 varieties of seeds were used as shown in tables 4, 5, 6, and 7. These were conducted for the purpose of making further observations as to the seeds chosen for oviposition that deductions could be made as to the underlying reason for such choices being made, and incidentally to determine the varieties in which this species of weevils is able to develop. In all experiments weevils having emerged during the preceding night or later, were used and are designated "newly emerged."

Experiment 7.

Twenty-five beans of each of the following varieties were placed in a pint Mason jar with 4 pairs of newly emerged weevils: Osceola velvet, biloxi soy, Mexican tree bean, mammoth yellow soy, O-too-tan soy. They are here listed according to size in descending order. In this group the number of eggs laid on each variety was more nearly proportional to the size of the seeds than in any other group. A total of 322 eggs were laid with a very marked preference being shown. Weevils emerged from only the three varieties of soy beans.

TABLE 4.

Showing Preference of Variety of Beans for Oviposition by 4 Pairs of *Bruchus quadrimaculatus*. August, 1922.

	Number of Eggs on Each Bean																									
O-too-tan Soy	0	2	0	1	0	1	1	3	1	0	0	0	0	1	1	1	0	0	0	0	2	1	2	0	1–	18
Biloxi Soy	2	2	1	1	2	2	2	2	1	2	3	3	1	1	1	2	2	1	2	2	1	4	0	2	2	44
Mammoth Yellow Soy	2	4	2	2	2	2	1	3	2	4	2	2	2	3	3	2	2	2	2	3	4	3	1	3	2	60
Mexican Tree Bean	2	4	4	4	3	5	3	2	3	2	3	2	7	1	3	3	2	1	2	2	3	4	3	3	4	75
Osceola Velvet	6	6	7	6	4	5	9	2	3	7	4	5	2	3	6	6	7	5	4	5	4	4	5	4	6	125
Total																										322

Experiment 8.

In this experiment 25 seeds of each of 6 varieties as shown in table 5 were placed with 6 pairs of newly emerged weevils. In this, as in all the other experiments the seeds were well mixed before the jars were laid on the shelf. The weevils were allowed to remain in the jar undisturbed until they were dead. The seeds were then separated and the eggs counted. Weevils emerged from only the American wonder pea and the broad windsor.

TABLE 5.

Showing Preference of Variety of Beans for Oviposition by 6 Pairs of *B. quadrimaculatus*, August, 1922.

	Number of Eggs on Each Bean																									
American Wonder Pea	2	0	0	0	0	0	1	0	0	0	0	1	0	2	1	1	1	1	1	0	0	0	0	0	0=	11
Broad Windsor	2	0	0	0	0	1	3	5	1	2	0	1	3	3	1	0	0	2	0	1	0	1	0	0	0	26
Navy	1	2	2	2	2	2	4	2	3	2	1	1	3	1	2	2	2	1	2	1	2	2	1	2	3	47
Full Measure Bean	2	6	3	3	6	3	3	4	1	2	1	3	3	5	6	3	3	1	4	4	1	7	3	4	4	85
Pink	2	3	2	4	5	4	5	6	4	4	5	4	4	3	3	2	4	2	4	3	2	3	4	5	4	91
King of Garden Lima	19	10	13	4	13	15	9	8	11	15	9	8	9	9	11	8	8	8	13	18	6	10	15	13	17	279
Total																										539

Experiments 9 and 10 were similar to the preceding experiments except that different varieties of seeds were used as shown in Tables 6 and 7. No weevils emerged from any of these seeds.

TABLE 6.

Showing Oviposition of 7 Pairs of *B. quadrimaculatus*, August, 1922.

	Number of Eggs on Each Bean																									
Tepary	1	1	1	1	2	1	1	1	0	1	1	2	1	0	0	0	0	0	1	3	1	1	0	1	3=	24
Creaseback	1	3	2	3	2	2	2	2	4	1	1	1	1	1	2	2	1	3	2	5	1	2	2	2	3	51
Reuters Longfellow	4	3	3	3	3	2	4	3	5	3	5	3	2	6	3	3	2	4	3	4	3	6	5	4	3	89
Wonderful Kidney Wax	4	6	5	4	4	6	3	3	3	1	5	5	2	3	7	5	3	1	6	6	3	6	5	3	9	108
Cranberry	6	5	6	3	4	4	5	4	3	6	4	4	5	7	6	4	7	5	6	7	4	3	6	4	3	121
Giant Pod Lima	6	9	12	10	10	5	3	7	5	3	10	4	11	5	9	9	5	5	3	7	8	10	7	6	6	175
Total																										568

TABLE 7.

Showing Oviposition of 6 Pairs of *B. quadrimaculatus*, August, 1922.

	Number of Eggs on Each Bean																									
Extra Early Refugee	1	1	1	3	2	1	4	2	1	4	3	2	2	1	1	4	2	2	0	1	1	2	1	4	4=	50
Refugee Wax	3	2	1	3	1	2	2	3	1	2	4	2	2	2	1	2	1	1	2	2	2	3	3	2	2	51
Prolific Black Wax	1	1	3	3	6	4	2	4	2	3	2	0	3	5	2	3	2	3	4	2	2	2	2	3	1	65
Canadian Wonder	4	5	5	3	6	4	5	4	5	3	4	7	3	4	6	3	5	4	8	4	5	6	4	3	5	115
Ventura Wonder Wax	5	4	5	3	3	5	5	4	5	5	3	4	4	7	4	5	4	6	8	5	4	4	6	5	5	118
Field Lima	8	9	8	7	6	2	8	7	7	6	3	6	3	5	5	4	7	5	7	6	8	8	5	6	3	149
Total																										548

EXPERIMENTS IN 1923.

Early in 1923 the writer received a number of varieties of seeds from the U. S. D. A. Bureau of Plant Industry. Because of the similarity of certain varieties of seeds it was necessary, while trying to determine the choice for oviposition and the hosts in which this weevil can breed, to divide these seeds into two groups as shown in Table 8 and 10. The weevils used throughout these experiments emerged from red ripper cowpeas after being bred there-in for 13 generations.

Experiment 11.

On July 5th, 5 pairs of newly emerged *Bruchus quadrimaculatus* were placed in each of 10 containers (pint Mason jar) with 5 seeds of each of the 23 varieties listed in table 8. These were placed in favorable location for observation. On July 13 the weevils were removed, the seeds were separated so that the eggs could be tabulated.

TABLE 8.
Choice of Seeds for Oviposition, July, 1923.

Kind of Seed	Number of Containers										
	1	2	3	4	5	6	7	8	9	10	Total
Vicia ervila	1	5	4	0	1	1	2	0	3	2	19
Vicia villosa	4	6	1	1	0	4	4	1	5	3	29
Lathyrus tingitanus	8	7	12	0	1	9	4	0	5	9	55
Mung bean	5	8	3	8	6	8	8	2	6	10	64
Urd bean	9	8	8	5	3	7	11	2	4	10	67
Vicia monantha	10	11	9	3	5	6	9	1	5	11	70
Lathyrus sativus	14	11	5	1	4	10	10	9	8	8	80
Rice bean	12	11	4	9	11	11	9	16	8	11	102
Cajanus indicus	14	11	13	3	8	11	14	15	12	19	120
Virginia soy	19	19	13	14	16	11	16	10	10	19	147
Hyacinth bean 47568	27	16	11	9	15	17	15	18	13	18	159
Hyacinth bean 27532	32	15	17	7	14	15	21	15	19	20	175
Wilson five soy	15	21	16	15	20	18	15	16	13	27	176
Buff catjang	22	16	17	23	15	24	18	22	18	19	194
Vicia faba	16	24	21	9	17	24	20	21	21	31	204
East cook soy	24	24	20	13	15	19	26	20	16	31	208
Adzuki-red	22	31	27	27	17	19	22	14	10	25	214
Brabham cowpea	28	25	29	20	25	22	16	20	16	22	223
Adzuki-speckled	30	31	29	30	20	26	23	19	23	23	254
Hahto soy	26	21	30	8	23	25	25	25	26	46	255
Conch	31	23	24	25	25	24	24	27	25	33	261
New Era Cowpea	31	24	31	27	25	23	27	29	23	28	268
Large blackeyed cowpeas	32	36	23	35	29	21	30	18	22	35	281
Total	432	404	367	292	315	355	369	320	311	460	3625

Although the number of eggs in the various containers varied from 292 to 460 the number of eggs oviposited on the different varieties of seeds holds quite a regular relationship in each container. More than 14 times as many eggs were laid on the large blackeyed cowpea as on black bitter vetch *Vicia ervilia.* A total of 3625 eggs were recorded. The emergence from these eggs is recorded in table 9, which shows that weevils emerged from all but 5 of the 23 varieties or in 11 different species of hosts.

TABLE 9.

Emergence Record of *B. quadrimaculatus* from 23 Varieties of Seeds, Eggs Laid July, 1923.

Kind of Seed	Number of Eggs	♂	♀	Number Emerged	Percent Emerged	Date of First Emergence	Date of Last Emergence	Second Generation
Vicia ervilia	19	0	0	0	...	...	...	...
Vicia villosa	29	0	0	0	...	...	...	...
Lathyrus tingitanus.	55	0	0	0	...	...	...	...
Mung bean	64	27	20	47	73.4	8-8	8-21	9-20—9-29 (8♂ 10♀)
Urd bean	67	0	3	3	4 4	9-21	10-13	...
Vicia monantha	70	0	0	0	...	...	...	...
Lathyrus sativus	80	18	22	40	50.	8-18	8-31	10-15—10-31 (10♂ 11♀)
Rice bean	102	0	0	0	...	...	...	...
Cajanus indicus	120	42	23	65	54 1	8-15	8-30	9-20—10-27 (19♂ 4♀)
Virginia soy	147	1	0	1	.6	10-20	...	...
Hyacinth bean 47568	159	25	26	51	32.	8-23	9-29	...
Hyacinth bean 27532	175	26	18	44	25.1	8-20	9-14	11-6—1♀
Wilson five soy	176	5	5	10	5 6	9-7	10-5	...
Buff catjang	194	64	52	116	59.7	8-6	9-29	11-6—1♂ 1♀
Vicia faba	204	2	3	5	2.4	8-23	9-11	...
East cook soy.	208	10	14	24	11.5	9-3	10-1	...
Adzuki-red	214	71	54	125	58 8	8-13	9-8	9-29—11-6 (23♂ 16♀)
Brabham cowpea	223	69	57	126	56 5	8-10	9-29	10-31, 1♂; 11-6, 1♂ 1♀
Adzuki-speckled	254	81	52	133	52.3	8-11	10-24	...
Hahto soy	255	17	21	38	14.9	9-3	10-1	10-27, 1♂
Conch	261	94	68	162	62.	8-9	10-10	...
New Er. cowpea	268	51	50	101	37 7	8-13	8-30	10-3—10-17, 5♂ 2♀
Large blackeyed cowpea	281	113	99	212	75.4	8-7	10-3	10-27—11-6, 8♂ 3♀
Total	3265	716	587	1303	36.2	8-6	10-24	

The difference in the ability of this weevil to develop in the various varieties is well marked, the emergence varing from 0 to more than 75 per cent. This record corroborates observations the writer has frequently made that when breeding in an unfavorable host there is usually a preponderance of males among those that are able to develop. This is sometimes noticeable when breeding in the more favorable hosts. As is indicated in the above table a second generation developed in several varieties as a result of eggs laid before the recorded weevils were removed.

Experiment 12.

In this experiment 2 pairs of newly emerged weevils were placed in each of 10 Mason jars with 5 seeds of each of the 10 varieties listed in Table 10. Here also the choice is very pronounced. Of the 1485 eggs more than 5 times as many were laid on the groit cowpea as on the lentils, *Ervum lens.* The emergence from these eggs is recorded in Table 11.

TABLE 10.

Choice of Seeds for Oviposition, July, 1923.

Name of Seed	Container Number										
	1	2	3	4	5	6	7	8	9	10	Total
Ervum lens	3	5	7	2	11	0	5	4	6	3	46
Vicia atropurpurea	4	6	5	6	7	5	8	2	7	4	54
Vicia dasycarpa	6	15	6	12	15	11	16	5	8	7	101
Lathyrus clymenum	9	9	13	12	12	11	12	4	13	14	109
Peking soy	9	21	13	17	19	10	14	7	12	12	134
Adzuki-buff	12	17	15	18	24	17	20	15	13	16	167
Manchu soy	21	18	17	24	29	19	24	1	17	20	190
Early red cowpea	13	23	19	23	19	36	19	23	17	17	209
Moneta cowpea	15	27	22	25	33	34	30	11	19	19	235
Groit cowpea	25	28	22	28	28	31	21	15	21	21	240
Total	117	169	139	167	197	174	169	87	133	133	1485

Here as in table 9 there is a great range in the ability of the weevils to breed in the different varieties. Here also ther were more males than females. Tables 9 and 11 indicate that the mung bean, *Cajanus indieus*, Buff catjang, and the Adzuki beans are as favorable for development as the cowpeas and only a little less favorable for oviposition.

TABLE 11.

Emergence Record of *B. quadrimaculatus* from Various Seeds.
Eggs Laid July, 1923.

Kind of Seed	Number of Eggs	♂	♀	Number Emerged	Percent Emerged	Date of First Emergence	Date of Last Emergence	Second Generation
Ervum lens	46	8	6	14	30.4	9–5	9–27	....
Vicia atropurpurea	54	0	0	0	....	....	....	....
Vicia dasycarpa	101	0	0	0	....	....	....	....
Lathyrus clymenum	109	0	2	2	1.8	9–4	9–4	....
Peking soy	134	0	0	0	....	....	....	....
Adzuki-buff	167	60	51	111	66.4	8–14	10–29	....
Manchu soy	190	3	4	7	3.6	9–11	9–22	....
Early Red cowpea	209	54	49	103	49.2	8–10	9–4	9-20—10-15, 58♂ 43♀
Moneta cowpea	235	82	53	135	53.1	8–10	9–13	9-20—10-15, 53♂ 38♀
Groit cowpea	240	24	23	47	19.5	9–11	10–23	....
Total	1485	231	188	419	28 2	8–10	10–29	....

Experiment 13.

On July 19, 5 pairs of newly emerged weevils were placed in each of 10 containers along with 5 seeds of each of the 29 varieties recorded in table 12, 3602 eggs were recorded, some being laid on all but two varieties of seeds. Previous experiments have shown that these two, the chick pea, and the little marvel pea, are favorable for the development of all stages of the weevil. The choice for oviposition on the 50 seeds of each variety ranged from nothing on the two varieties and 3 on the broad windsor to 308 on the bush lima. This was more than 100 times as many eggs on a variety which is favorable for oviposition but in which the weevil cannot develop, as were laid on à variety of equal or greater size which was unfavorable for oviposition but in which the weevil can develop.

Table 13 shows the emergence from the eggs recorded in Table 12. It corroborates the findings in the preceding experiments with no emergence from many varieties and with an emergence of less than 4 percent in some of the soy beans to 82.5 percent in the red ripper cowpeas. In this experiment as in all those preceding it, the eggs hatched normally on all varieties of seeds. Even in the most favorable varieties there is a higher mortality amongst the larvæ of the first stage than of any later stage. In fact in these varieties under normal conditions there is practically no mortality after the first larval stage. In the soy beans it appears that the mortality is greatest a few days after the larvæ have entered the seed or in the second larval stage, but there is a high mortality and a retarded development in all the larval stages. In the common beans and some other varieties of seeds the larvæ appear to die shortly after eating the first bit of the cotyledon.

TABLE 12.

Choice of Seeds for Oviposition, July, 1923.

Kind of Seed	Number of Containers										
	1	2	3	4	5	6	7	8	9	10	Total
Little Marvel Pea	0	0	0	0	0	0	0	0	0	0	0
Chick pea	0	0	0	0	0	0	0	0	0	0	0
Broad Windsor	0	0	0	0	2	0	1	0	0	0	3
P. vulgaris, Vari. unknown	3	3	1	2	2	4	0	6	6	4	31
O-too-tan soy bean	5	5	1	3	3	3	4	2	5	2	33
Castor bean	0	0	3	5	3	1	10	8	6	3	39
Pinto bean	2	7	1	5	8	3	9	5	10	1	51
Navy bean	11	7	1	7	8	2	12	5	10	4	67
Kentucky Wonder	7	5	2	7	8	3	11	7	14	7	71
Kentucky Wonder (brown)	7	6	5	7	17	6	7	11	15	9	90
Lazy Wife	5	11	3	12	11	4	14	11	9	11	91
Biloxi soy	8	11	4	10	14	10	7	12	10	9	95
Mammoth yellow soy	9	9	8	10	19	6	12	12	11	6	102
Prolific black wax	11	8	5	5	13	7	19	13	13	8	102
Velvet bean	6	7	5	9	15	9	13	12	20	12	108
Extra early refugee	9	11	6	6	13	5	18	15	14	12	109
Improved six weeks	13	11	4	4	16	3	20	12	13	19	115
Early Mohawk	14	12	4	6	11	10	18	14	17	15	121
Canadian Wonder	19	13	3	12	28	4	19	18	19	17	152
Scarlet runner	5	22	1	11	35	20	19	20	15	18	166
Red Kidney	16	7	13	17	29	12	23	19	24	19	179
Blackeye	24	19	34	26	22	23	6	8	16	8	186
Improved golden wax	21	16	17	15	20	18	24	27	23	15	196
Red ripper	29	9	30	23	12	29	9	18	28	14	201
Ventura Wonder Wax	30	20	14	19	33	20	26	18	24	24	228
Speckled cranberry	29	14	12	19	37	25	23	22	26	27	234
Holstein	37	26	26	26	21	41	14	19	33	13	256
Fordhook lima	25	19	17	21	33	15	28	35	29	36	258
Burpee's Imp. Bush Lima	27	19	28	36	38	17	39	42	29	33	308
Total	372	297	258	323	471	300	405	391	439	346	3602

TABLE 13.

Emergence Record of *B. quadrimaculatus* on Various Seeds.
Eggs Laid July, 1923.

Kind of Seed	Number of Eggs	♂	♀	Number Emerged	Percent Emerged	Date of First Emergence	Date of Last Emergence	Second Generation
Little Marvel Pea...	0	0	0	......	....	....	....	....
Chick Pea..........	0	0	0	......	....	....	....	....
Broad Windsor......	3	0	0	......	....	....	....	....
P. vulgaris, vari. unknown..........	31	0	0	......	....	....	....	....
O-too-tan soy bean..	33	3	3	6	18.1	9-15	10-24	....
Castor bean.........	39	0	0	......	....	....	....	....
Pinto bean..........	51	0	0	......	....	....	....	....
Navy bean.........	67	0	0	......	....	....	....	....
Kentucky Wonder..	71	0	0	......	....	....	....	....
Brown Kentucky Wonder...........	90	0	0	......	....	....	....	....
Lazy Wife..........	91	0	0	......	....	....	....	....
Biloxi soy...........	95	4	1	5	5.2	9-27	10-2	....
Mammoth Yellow soy...............	102	7	0	7	6 7	8-29	10-1	....
Prolific Black Wax..	102	0	0	......	....	....	....	....
Velvet bean.........	108	0	0	......	....	....	....	....
Extra Early Refugee	109	0	0	......	....	....	....	....
Improved six weeks	115	0	0	......	....	....	....	....
Early Mohawk......	121	0	0	......	..¼....	....	....	....
Canadian Wonder...	152	0	0	......	....	....	....	....
Scarlet Runner......	166	0	0	......	....	....	....	....
Red Kidney........	179	0	0	......	....	....	....	....
Blackeyed cowpea..	186	92	54	146	78.5	8-23	9-6	10-3—10-29 (6♂ 8♀)
Improved Golden Wax..............	196	0	0	......	....	....	....	....
Red Ripper Cowpea	201	72	94	166	82.5	8-23	9-5	10-3—10-15 (9♂ 11♀)
Ventura Wonder Wax	228	0	0	......	....	....	....	....
Speckled cranberry.	234	0	0	......	....	....	....	....
Holstein Cowpea....	256	88	70	158	61.7	8-23	9-8	10-3—10-20 (3♂ 1♀)
Fordhook Lima.....	258	0	0	......	....	....	....	....
Burpee's Imp. Bush Lima............	308	0	0	......	....	....	....	....
Total......... ..	3602	266	222	488	13 5	10-24	....	....

The following is a list of seeds from which the writer has bred *Bruchus quadrimaculatus* experimentally:

Early rams horn blackeyed cowpeas, *Vigna sinensis*,
Mammoth blackeyed cowpea,
Blackeyed cowpea of two or three other strains,
Groit Cowpea,
Black,
Wonder or Unknown,
Early Red,
Moneta,
Whip-poor-will,
Brabham,
Peking,
White crowder,
New Era,
Holstein,
Red ripper,
Iron,
Clay,
Wilson,
Blackeyed brown,
Yard long or asparagus bean *Dolichos sesquipedalis*,
Cajanus indicus,
Lentils *Ervum lens*,
Garbanzo or chick pea *Cicer arietinum*,
Tarheel black soy *Glycine hispida*,
Biloxi soy,
O-too-tan soy,
Mammoth yellow soy,
Virginia soy,
Wilson five soy,
Easy Cook soy,
Hahto soy,
Machu soy,
Prizetaker pea *Pisum sativum*,
American Wonder,
Dwarf Telephone,
Admiral,
Little Marvel,
Hulbert field,
Warshaver field,
Canada field,
Colorado stock,
Chickling vetch, *Lathyrus sativus*,
Lathyrus *Lathyrus clymenum*,
Bitter vetch *Vicia ervilia*,
Bitter vetch, Different strain,
Broad windsor or horse bean *Vicia faba*,
Small windsor *Vicia faba*,
Buff catjang,
Adzuki-red *Phaseolus angularis*,
Adzuki-speckled *Phaseolus angularis*,
Adzuki-buff *Phaseolus angularis*,
Mung bean *P. aureus*,
Urd bean *P. mungo*,
Hyacinth bean (47568). (No. given by Bureau of Plant Industry),
Hyacinth bean (27532). (No. given by Bureau of Plant Industry),
Conch bean.

Most of the varieties here recorded have been used repeatedly in unlisted experiments to check on the ability of this weevil to breed therein. In some instances, notably with soy beans and broad and small windsor beans it has been found that the weevil failed to develop in certain lots while it developed in others. This seems to indicate that under certain conditions seeds of a given variety may be more toxic to young larvæ than under other conditions. It is very probable that *B. quadrimaculatus* may be found to be able to breed in many more varieties of seeds which have been unavailable for these experiments. Under some conditions it may even breed in some in which the writer has been unable to get it to develop.

The fact that this weevil oviposits freely on many varieties of common garden beans and is therefore found quite frequently amongst such beans probably accounts for the erroneous statements so frequently made that it works in common beans. The results of experiments with 50 or more varieties of *P.*

vulgaris which includes the common garden beans, seems to indicate that they are quite unsuitable for the larval development of this weevil.

The following is a list of seeds from which the writer has not been able to breed it, although eggs have been deposited more or less freely on each variety:

Red Valentine Bean, *Phaseolus vulgaris*,
Brown Kentucky Wonder,
Lady Washington,
Prolific Black Wax,
Improved Golden Wax,
Pinto,
Colorado Pinto,
Hanson Yellow,
Bates,
California Pink,
Dwarf Spanish,
Nicaragua,
Black Valentine,
Burpee's Stringless Greenpod,
Baldwin's Wonder Wax,
Eastern Cornfield,
Long Yellow Six Weeks,
Mexican Red,
Kentucky Wonder Wax,
Superior Kentucky Wonder,
Brown Kentucky Wonder,
White Kentucky Wonder,
Lazy Wife,
Cranberry,
Dutch Caseknife,
Early Mohawk,
Improved Early Mohawk,
Italy's Favorite,
Bayo,
Red Kidney,
Black Wax,
Navy,
Navy Bluepod,
Large White,
Small White,
Creaseback,
Reuter's Longfellow,
Wonderful Kidney Wax,
Refugee Greenpod,
Ventura Wonder Wax,
Full Measure (and 9 other varieties of *Phaseolus vulgaris*, whose common names are unknown to the writer)
Rice Bean *Phaseolus calcaratus*,
Tepary *P. acutifolius*,
Scarlet Runner *P. multifloris*,
Large White Lima *P. lunatus macrocarpus*,
Giant Pod Lima,
Ford Hook Lima,
Field Lima,
King of Garden Lima,
Henderson Bush Lima *P. lunatus*,
Moki Lima,
Velvet Bean *Stizolobium* sp?,
Chinese White Velvet Bean,
Early Bird Velvet Bean,
Mexican Tree Bean,
Castor Bean *Ricinus communis*,
Woolly Podded Vetch *Vicia dasycarpa*,
Vetch *V. monantha*,
Purple Vetch *V. atropurpurea*,
Hairy Vetch *V. villosa*,
Oregon Vetch *V. sativa*,
Narrow-leafed Vetch *V. angustifolia*,
Vetch *P. pamonica*,
Tanager pea *Lathyrus tingitanus*,
Hickory King Corn *Zea maise*,
Bloody Butcher Corn,
Several kinds of Indian Corn,
White Kaffir Corn,
Honey Drip Sorghum,
Speltz,
Burbank Superior Wheat,
Kanred Wheat,
Turkey Red Wheat,
California Red Oats,
Common Buckwheat,
Japanese Buckwheat,
Egyptian Cotton.

In every variety of the above seeds, except the Egyptian Cotton, the young larvæ have bored through the seed coat, but in no case did the tiny weevil develop to any appreciable extent before dying. Many of the larvæ died before their bodies were entirely out of the egg shells, but others were able to gnaw minute holes through the testa of the seeds, and still others penetrated a short distance into the cotyledons.

It has not been determined that this weevil would be able to pass through its later larval stages in any of these hosts which prove fatal to all first stage larvæ. After repeated failure in getting the larvæ to live when transferred from blackeyed cowpeas to pink beans the writer tried transferring larvæ from blackeyed cowpeas to other blackeyed cowpeas. In order to make such a transfer it is necessary to dissect a larva out of one seed and insert it into another. Because of the body structure and the feeding habits of the larvæ, it was difficult to make a cavity in the new seed which was suitable.

When the larva hatches it depends upon the egg shell to support its prothoracic plates, which Kannan (33) points out, are used as levers for bracing and shifting the body as the latter by means of a peristaltic movement, enables the chisel like mandibles to drill or chissel off tiny bits of the host. The older larvæ depend upon the walls of the cavities to support their bodies as the choria supported the young larvæ while they were effecting entrance. From the time the insect enters the seed the cavity is enlarged proportionally to the growth of the body. Frequently a larva will break the wall of its cavity and fall or wiggle into the central cavity so generally found in the blackeyed cowpea and there will die or gouge out some food on each side and pupate within this central cavity. Weevils that pupate in this cavity usually are undersized because of lack of food and the adult dies without making an exit. When a large larva enters the central cavity of the seed it has a better opportunity to brace its body and make a cavity to fit its body thus being enabled to make its way near the outer surface of the seed before pupating. Young larvæ frequently enter the chambers made by larger larvæ and there die of starvation.

The writer when transferring larvæ from one bean to another was unable to overcome the difficulty of getting a properly fitted cavity. Only a few weevils thus transferred from one blackeyed cowpea to another were successful in reaching maturity. These were undersized. None developed when transferred to garden beans.

Some larvæ transferred into and buried with finely powdered blackeyed cowpeas were retarded in their development but finally emerged as adults but the majority failed to emerge. None emerged from flour made from garden beans.

Retarded development of the larvæ which were buried in flour made from the cowpeas seems to indicate the inability of the larvæ to obtain sufficient food for proper development and not that the food which was ingested was unsuitable for growth. Total failure to develop when thus buried in bean flour seems to indicate that this material was unsuitable for food. In this connection Bridwell (32) says: "It is not improbable that the inability of bruchids to breed in legumes otherwise similar in composition to their host seeds may be due to the diversity of their proteids."

Retarded development of the larval stages within soy beans appears to be due to one of the two causes; first, the inability of the larvæ to obtain sufficient food and second the lack of some necessary elements. If the latter were the chief cause it would seem that a very much greater percentage would die in the first stage; that only a very few would reach the second stage. However, it appears that more larvæ die in the second stage and in each succeeding stage than die in the first larval stage. The writer interprets this to indicate the inability of the second stage larvæ to obtain sufficient food. The first stage larvæ are able to get sufficient food because their prothoracic plates are better developed and used more in this stage than in any other. In this stage the use of these plates enables the larvæ to hold the body firmly in the desired position while food is being obtained. In the later stages the larvæ depend less on these plates and more on the rest of the body. The body appears to be unable to hold firmly in position within the cavity of the oily soy bean. The body with the less functional prothoracic plates skid so to speak, causing the larvæ to die of slow starvation or to develop slowly. The emerging adults are reduced in vigor and vitality and produce only a few eggs so that a heavy infestation dies out in a few generations.

So far the writer has not been able to prove definitely that the retarded development is not due to a lack of some necessary element. A quite similar retarding of development can be noticed within cowpeas when there is an insufficient air supply as is the case when the cowpeas are kept inside of vials sealed with paraffined corks. If the enclosed seeds are only lightly infested the development of the later larval stages is retarded. If the seeds are heavily infested the larval development is greatly retarded or even killed. When a lack of air causes a slow larval growth it causes a high mortality of the pupæ. This high death rate among the pupæ seems to be due to the complete vitiation of the air. Such a condition does not exist within the soy beans. There is no evidence to indicate that the weevils within the soy beans in normal or unsealed containers do not obtain sufficient air. The mortality amongst the pupæ is not great enough to indicate an accumulative effect as is indicated in the cowpeas.

The foregoing experiments indicate that this weevil oviposits freely on a great many varieties but it shows a consistant choice of certain varieties in nature or in experiments.

It oviposits freely on some varieties even in which there is a total mortality of the young larval stage but it shows a marked hesitancy in ovipositing on other varieties in which the young larvæ cannot survive. Again oviposition occurs freely on some seeds in which the mortality of all larval stages is high but from which some individuals emerge as adults. While it oviposits freely on certain varieties which are favorable for all stages of development it almost refuses to oviposit on other varieties which seem to be equally favorable for larval development. For example there seems to be no higher larval mortality in the chick pea than in any of the cowpeas but the weevil seldom oviposits on the former when the latter are equally available.

This indicates that there are certain seeds which are favored for oviposition and certain ones which are avoided. The fact that the weevils consistantly avoid ovipositing on certain varieties of seeds even after having bred therein for several generations indicates that there is no inherited predilection for that host. Continued breeding in a host does not appear to intensify the preference for that host.

There seems to be a predilection for seeds having smooth well filled coats. This has been borne out by all the foregoing experiments. It is further borne out by the fact that the weevil oviposits quite freely on painted lead pencils, varnished handles, door frames which have been stained and varnished, but refuses to oviposit on rough or unpolished wood.

That the sense of touch is very highly developed in the adult weevils is indicated by the fact that they never oviposit on split beans or broken seeds of any variety where sound seeds can be found. Cowpeas or other seeds having seed coats which have become loosened are always passed over if other seeds are available. Some seeds have wrinkled coats while others have smooth coverings. The weevil's sense of touch seems to be able to differentiate between these two types of coverings. This is illustrated better with the Holstein cowpeas than with any other that I have noticed.

This cowpea seems to be a direct cross between a black smooth skinned cowpea and a white rough skinned variety. It is variable in color markings as well as in the texture of the seed coat, there being all gradations from white with a few black spots to black with a small white area, and from smooth to quite wrinkly. Some of these seeds have coats which are partly smooth and partly rough. On seeds of this kind the choice of the weevil is frequently quite noticeable, the smooth area having been oviposited on while the other portion of the seed is free from oviposition.

That some factor besides the smoothness of the seed coat may have a bearing on the choice of seed for oviposition is evidenced by the way the tepary bean is avoided. The surface of this bean appears to be as favorable as that of several other varieties which are selected while it is not. There is a difference between the seed coat of this bean and any other with which the writer is familiar in that as soon as it is moistened it begins to wrinkle. This difference is not apparent until the seed coat is moistened.

If the sense of touch is responsible for the selection of seeds for oviposition as it appears to be, the next question is, where this highly developed sense organ is located. Is it the antennae or the mouthparts or the feet and legs, or is it the ovipositor? The writer after studing the oviposition of numerous weevils is inclined to think that all of these parts of the weevil function in this respect. The weevil will walk over some seeds without showing any reaction while it will carefully feel others with its antennae, its mouthparts and finally extrude its ovipositor several times before selecting a location for the egg. On other seeds it will oviposit without giving any apparent concern to the location. In some cases the feet and legs appear to determine the desirability or the undesirability of the seeds.

The egg is surrounded by a gelatinous liquid which soon hardens and cements it to the host. The weevil apparently never turns around to examine the spread of this cement around the egg.

CONCLUSIONS.

Bruchus quadrimaculatus Fab. which normally breeds in cowpeas can breed in many varieties of leguminous seeds.

Oviposition takes place more freely on well matured seeds of any variety than on unmatured or broken seeds of the same variety.

The adults show a marked predilection for well filled seeds having a smooth polished seed coat.

With reference to the choice for oviposition, seeds may be divided into the following groups:

1. Seeds which are favorable for oviposition:
   (a) Seeds which are favorable for all stages of development, cowpeas furnishing examples.
   (b) Seeds in which weevils cannot develop, some of the limas and common beans *P. vulgaris* being examples.
2. Seeds which are less favorable for oviposition:
   (a) Seeds which are favorable for all stages of development, some varieties of cowpeas and Adzuki beans being examples.
   (b) Seeds which are unfavorable for development in some stages, but in which some weevils are able to develop, soy beans being examples.
   (c) Seeds in which the weevils do not develop, many common beans *P. vulgaris* are examples.
3. Seeds which are unfavorable for oviposition:
   (a) Seeds which are favorable for all stages of development, Chick peas are an example.
   (b) Seeds which are unfavorable for development in some stages, broad windsor for example.
   (c) Seeds in which the weevils can not develop, the tepary is an example.

The adults show no marked predilection for the host in which they have bred.

Continued breeding in a host does not appear to intensify the preference for that host.

The adult oviposits as freely on hosts which are unfavorable for larval development as on hosts which are favorable for such development.

Any inherited tendency toward the formation of host strains or phytophagic species would have to be exhibited by the adult only, because the eggs are glued to the host and the young have no means of gaining access to a host if the egg is not firmly attached. Any host which is unfavorable to the young larvæ precludes the possibility of its being favorable to later stages.

The Host-Selection Principle as outlined by Hopkins does not appear to hold with this insect.

The four-spotted bean weevil *Bruchus quadrimaculatus*, does not appear to be able to breed in any variety of common garden beans *Phaseolus vulgaris*.

Because of the inability of *Bruchus quadrimaculatus* to breed in common beans, its misleading common name should be changed to "four-spotted cowpea weevil."*

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EXPLANATION OF PLATE IV.

Fig. 1. Horse Beans of Broad Windsor, showing *a*, Eggs of 4-spotted cowpea weevil; *b*, Eggs removed to show entrance holes; *c*, Part of seed coat removed.

Fig. 2. Eggs of *B. quadrimaculatus* on lead pencils and handle of dissecting needle.

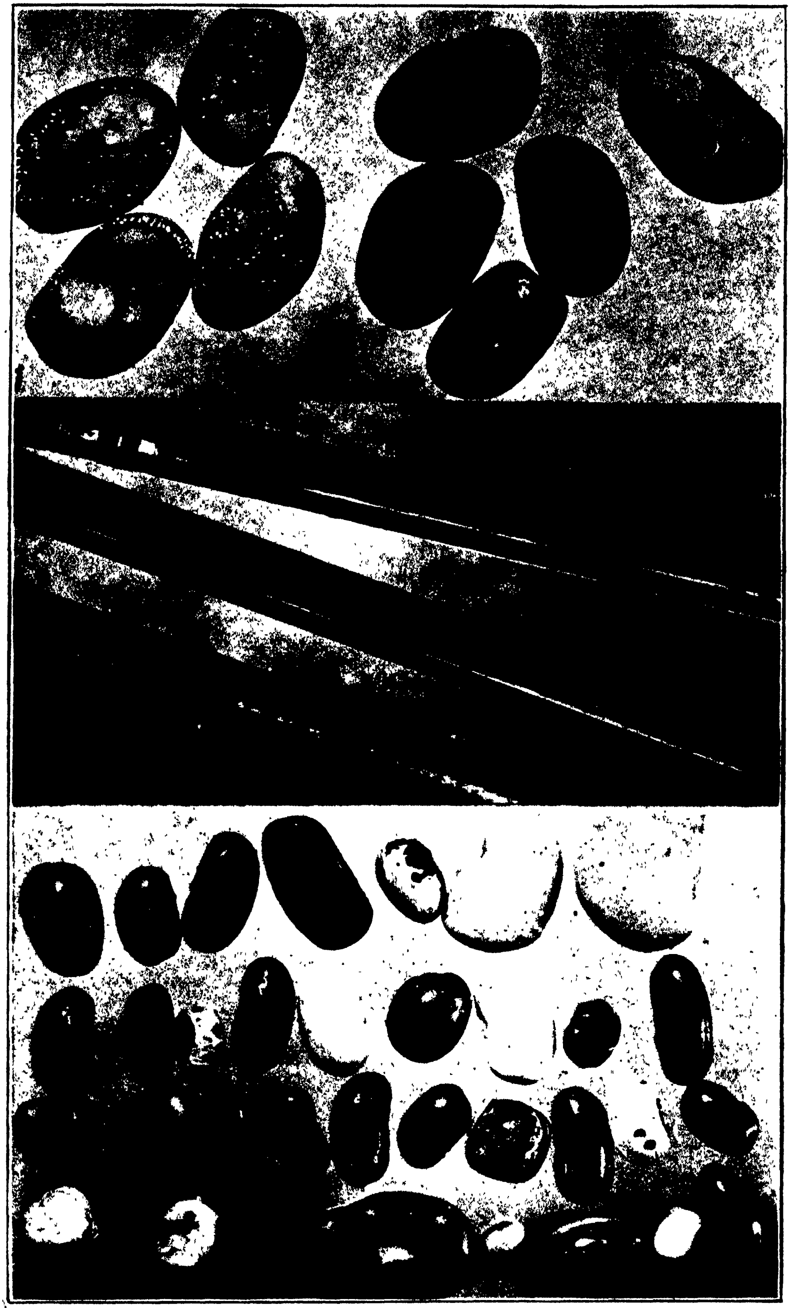
Fig. 3. Beans used in experiment to show varieties preferred by *B. quadrimaculatus* for oviposition. Listed in ascending order with reference to number of eggs laid.

Lower left: 1, Garbanza; 2, Lentil; 3, Prizetaker pea; 4, Dwarf Sugar pea; 5, Broad windsor; 6, Mammoth Yellow Soy; 7, Common bean (variety unknown); 8, Nicaragua; 9, Black Valentine.

Second row left: 10, Small Windsor; 11, Pink; 12, Burpee's Stringless Green Pod; 13, Baldwin Wonder Wax; 14, Eastern Cornfield; 15, Pinto; 16, Velvet; 17, Improved long yellow six weeks; 18, Blackeyed cowpea; 19, Mexican Red.

Third row left: 20, Kentucky Wonder Wax; 21, Red Valentine; 22, Holstein cowpea; 23, Brown Kentucky Wonder; 24, Lazy Wife; 25, Cranberry; 26, Dutch Caseknife; 27, Red Ripper cowpea; 28, Early Mohawk.

Fourth row left: 29, Italy's Favorite; 30, Bayo; 31, Red Kidney; 32, Scarlet runner; 33, Improved Golden Wax; 34, Bush Lima; 35, Fordhook Lima.



A. O. Larson

NOTES ON THE BIOLOGY OF THE MEAL WORMS, TENEBRIO MOLITOR LINNE AND T. OBSCURUS FAB.

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INTRODUCTION.

Owing to their usefulness as food for birds, reptiles, fish and small mammals, their desirability for anatomical and genetical research (for they are large in size and easily reared), and their destructiveness as pests of flour, meal, grain, etc., the meal worms have been well known for centuries. Many interesting accounts of the two species, *Tenebrio molitor and T. obscurus*, have been published, but aside from the brief observations of Riley in 1883 (6), Chittenden in 1895 (3) and 1896 (4), and Rau in 1915 (5), but little accurate information has been obtained on the biology of the meal worms in North America. Arendsen Hein, working in Europe on variations occurring in the different stages of the meal worms, made many observations on their life histories, and in 1920 (1) and 1923 (2) published valuable data on the biology of these two species. The writer has made observations on the life histories of the meal worms for the past three years and has gathered many data, some of which are presented in the following pages.

DISTRIBUTION.

The meal worms are undoubtedly cosmopolitan in distribution and have probably been introduced into every section of the United States. *Tenebrio obscurus* is occasionally reported as injurious from all parts of the country, but *T. molitor* is never reported from the southern states and apparently thrives only in the more northern states.

BIOLOGY.

At Washington, D. C., the meal worms normally pass the winter in the larval state. The adults emerge in the spring and early summer months, live for from two to three months and die. In the natural state there is, therefore, but one full generation a year. In the laboratory an occasional individual of *Tenebrio obscurus* completed its development from egg to adult in as short a time as four months, transforming in June, July, or August instead of waiting until the following spring; on the other hand, a number of individuals of the same species required two years to complete their development, although all were reared under the same conditions. Under similar conditions no specimens of *Tenebrio molitor* completed their development in less than ten months, and slightly more than half of the specimens reared individually required two years to complete their development. When reared in an incubator with continuous favorable conditions of temperature, moisture, and food, both species bred uninterruptedly the year around and all stages were obtained at all times of the year.

THE ADULT.

The meal worm beetles closely resemble each other in size and form but *Tenebrio molitor* is shining and almost black in color, while *T. obscurus* is a dull pitchy black. Both species are nocturnal in habit and may occasionally be seen at night attracted to bright lights.

At Washington the adults normally begin to appear in the spring and from then on may be seen all through the summer. The adults of *T. obscurus* are the first to be seen, many of them emerging a month or more before the first appearance of *T. molitor.* In the laboratory, which was heated during the day in winter, adults of *T. obscurus* emerged in every month of the year. Larvæ of the first generation began to pupate as early as June, a few adults emerged in June and July, and with each succeding month the numbers of emerging adults increased until the peak was reached in February. Adults of *T. molitor* did not begin to emerge in the laboratory until January, the peak of the emergence also occurring in February.

LONGEVITY.

Compared with many of the stored grain pests, the adults of the meal worms are relatively short lived. Statistics of several hundred specimens reared in the laboratory showed that the length of life of the female adults of *T. molitor* ranged from 37 days as a minimum to 96 days as a maximum, with an average of 65 days; the length of life of male adults ranged from a minimum of 39 days to a maximum of 92 days, with an average of 58 days. Female adults of *T. obscurus* ranged in length of life from a minmum of 42 days to a maximum of 152 days, with an average of 84.5 days; male adults ranged in length of life from a minium of 31 days to a maximum of 132 days, with an average of 83.4 days.

OVIPOSITION.

Mating takes place within a few days after emergence and, once fertilized, the female beetles are capable of producing fertile eggs practically throughout the egg-laying period. The preoviposition period ranges from about one to three weeks, being influenced chiefly by the temperature.

The meal worm beetles are relatively prolific egg layers. Females of *Tenebrio obscurus* reared in the laboratory desposited an average of 463 eggs. the smallest number laid by one female was 73 the largest number 970. Females of *T. molitor* deposited an average of about 276 eggs each. The smallest number laid by one female was 77, the largest 576.

The oviposition period of the meal worm beetles is comparatively short when compared with other beetles infesting stored products. The oviposition period of *Tenebrio obscurus* females reared in the laboratory ranged from a minimum of 22 days to a maximum of 137 days. Similarly, the oviposition period of *T. molitor* females ranged from a minimum of 21 days to a maximum of 67 days.

The rate and frequency of oviposition varies considerably. Beetles reared in the laboratory at times made daily ovipositions for as many as 17 consecutive days, at other times there were intervals of from one to nine days between ovipositions. Occasionally but one egg was laid during a twenty-four hour period, while at other times as many as 60 eggs were laid during a like period. The greatest number laid by an adult of *T. obscurus* during a twenty-four hour period was 62, the greatest number laid by an adult of *T. molitor* during a similar period was 40. The following data will give some idea of the rate and frequency of oviposition of the meal worms: On fifteen consecutive days the number of eggs laid by a female of *T. obscurus* were 10, 0, 20, 0, 18, 0, 0, 21, 0, 0, 25, 0 20, 25, 0. For the same period another female deposited 10, 11, 2, 17, 3, 5, 15, 2, 5, 9, 4, 8, 16, 10, 12 eggs. Similarly, a female of *T. molitor* deposited 10, 0, 7, 9, 8, 13, 26, 17, 5, 0, 15, 19, 7, 0, 10 eggs on 15 consecutive days, and another female 22, 14, 8, 4, 16, 10, 12, 14, 8, 24, 14, 12, 10, 14, 2.

THE EGG STAGE

The white, oblong-oval eggs are laid singly or in small clusters, usually loosely in the flour or meal in which the insects are breeding. When first laid they are covered with a sticky secretion that causes them to become quickly coated with the particles of food in which they are deposited. The incubation period varies considerably in both species and is influenced chiefly by the temperature. With a mean average temperature ranging from 80° to 88° F., the egg stage lasts for from 4 days to a week, while with the mean average temperature ranging from 65° to 70° F., the period may be lengthened to as much as 19 days.

LENGTH OF LARVAL STAGE.

The length of the larval stage varies considerably and is influenced by several factors. At Washington, D. C., both species of meal worms normally require at least one year for development under storehouse conditions. In the case of *Tenebrio obscurus* a few larvæ that hatch in the early part of the year complete their growth and transform in midsummer, a few remain as larvæ for two years before transforming, but the majority transform at the end of the first year during the spring and early summer months. The shortest larval period observed was 79 days, covering the period from March 15, 1924, to June 2, 1924. The longest larval period observed was 642 days, covering the period from April 5, 1923, to January 6, 1925. The shortest normal larval period recorded for *T. molitor* was 281 days, covering the period from July 25, 1923, to May 1, 1924; the longest larval period recorded was 629 days, covering the period from June 26, 1922, to March 16, 1924. Of all specimens bred through in the laboratory, more than half required more than one season to complete their growth. Specimens reared in an incubator with continuous favorable conditions of temperature, humidity, and food completed the larval stage in six months.

NUMBER OF MOLTS.

The number of larval molts varies somewhat. Twelve was the smallest number of molts recorded for a single larva of *Tenebrio obscurus* during its entire period of development, while the greatest number recorded for any one larva was 22. Approximately half of all the specimens reared molted either 14 or 15 times each. The smallest number of molts recorded for a larva of *T. molitor* was 9 during the entire larval period, and the greatest number recorded for any one larva was 20. Approximately half of the specimens reared molted either 17, 18, or 19 times each.

PUPATION.

After becoming apparently full grown the larvæ may transform to the pupal form or may remain for many months with but little change in size or outward appearance.

In the laboratory at Washington, which was heated during the winter, the larvæ of *Tenebrio obscurus* began to pupate in numbers in November and continued throughout the winter and spring months. A few of the larvæ that hatched very early in the year pupated as early as June of the same year, and pupæ were obtained in small numbers during each succeeding month until November, when their numbers increased. In barns, storehouses, etc., that are unheated during the winter months, the larvæ do not pupate normally until spring or early summer.

The larvæ of *T. molitor* do not begin to pupate so early in the season as those of the foregoing species. In the laboratory the first pupæ were obtained in late January but in unheated warehouses, storehouses, etc., they do not normally pupate until May or June.

When about ready to pupate the larvæ of both species come to the surface of the foodstuff in which they are living and pass through a short prepupal period during which they are sluggish and exhibit few signs of life.

DURATION OF PUPAL STAGE

The length of the pupal stage is dependent chiefly on the prevailing temperature conditions. The pupal stage of *Tenebrio obscurus* ranged in length from a maximum of 20 days during

January and February, with a mean average temperature of 65° F., to a minimum of 7 days in June and July, when the mean average temperature ranged from 77° to 78° F. The pupal period of *T. molitor* ranged from a maximum of 18 days during February, with a mean average temperature of 65°F., to a minimum of 6 days in June, with a mean average temperature of 81° F.

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ANOTHER INTERMEDIARY INSECT HOST OF THE GIANT THORN-HEADED WORM OF SWINE*

Phyllophaga vehemens Horn (Scarabaeidae)

New to the Host List of this Parasite

By Robert D. Glasgow.

In the course of a search for hitherto unrecognized intermediary insect hosts of the giant thorn-headed worm of swine, *Macrocanthorhynchus hirudinaceus* (Pallas) Travassos, another step forward is marked by the discovery that *Phyllophaga vehemens* Horn is an acceptable host species for the larval development of this parasite.

Not only may the cysts of the parasite develop in *P. vehemens* grubs that have been fed upon material contaminated with eggs of the worm, but the cysts may persist through the transformation of this host species, and may probably be transported from one field to another by the flight of the infested adult beetles. In one instance, sixty-seven mature cysts of the giant thorn-headed worm were found in a single female adult of *Phyllophaga vehemens* Horn.

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*Contribution from the Entomological Laboratories of the University of Illinois, Number 116.

SOME NON-NERVOUS FACTORS THAT CONDITION THE SENSITIVITY OF INSECTS TO MOISTURE, TEMPERATURE, LIGHT AND ODORS.*

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Ohio State University.

Insects are so extraordinarily sensitive to moisture, temperature, light and odors that much of our recent investigation in entomology has centered on the problems of this supersensitiveness. Just at present several large projects in economic entomology include experimentation on attractants while in other projects careful studies are being made of the correlation of possible spread with moisture and temperature conditions. All such studies presume sensitivity of insects to these factors.

The unerring and delicate response of insects to odor, light, temperature and moisture is uncanny to the human species where such reactions have become dulled as reason has developed. Male moths have been known to find the female of their species a mile away. When we figure out the physics of the problem and see what this means in the very small number of infinitesimal odor particles that must have been picked up by the chemoreceptors of the male at that distance and yet became the stimulus to move his entire body a mile, his hypersensitiveness appears nothing short of miraculous. Many insects are almost equally sensitive to quality of light. I have had stoneflies go by a three hundred candle power gas mantle lantern on the creek bank to a seventy five watt Mazda nitrogen light a half mile away, where they appeared in abundance while none appeared on my collecting sheet at the creek. Only a difference in quality of light accounts for this, the Mazda light probably giving more ultraviolet, but when we figure out the intensity of a seventy five watt light at one half mile, this reaction is in the same category of sensitiveness as that of the sense of smell of the male moth.

Sensitiveness to temperature and moisture differences is usually not so delicately developed in insects as that to odors and light. This difference is probably due to the fact that odor and light stimuli have to affect only the sense receptors, while temperature and moisture changes usually have to affect the condition of the whole body before becoming effective. Raising or lowering the body temperature or changing its moisture content takes an appreciable time, even if this change concerns only the surface, which makes temperature and moisture reactions noticeably slower than those to light and odor. The recent experiments of Miller and Gans[1] and of Shapley[2] on ants show that insects are very sensitive to changes of temperature. As worker ants are blind or nearly so, they make excellent subjects for the study of reaction to temperature. Insects also are very sensitive to moisture conditions which at first sight is unexpected because the impervious chitinous wall would seem an almost perfect protection against desiccation. These reactions to differences in moisture are slow but are very distinct when time enough is given as has been shown by recent unpublished work on the Mexican Bean Beetle, the European Corn Borer,[3] etc. The reaction time for temperature and moisture is so very much slower than that for odor and light that it is in a very much lower order of speed.

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*Contribution from the Department of Zoology and Entomology, Ohio State University, No. 92.

This general sensitiveness of insects is of a delicacy of reaction that seldom appears in the higher vertebrates. In the latter forms we recognize sensitiveness to all these factors but their reactions are less evident in that a greater range of stimuli is usually necessary to compel much change in orientation or distribution. As I shall show later, their larger size which permits warm blood and their larger and more complex central nervous system modify their behavior so that it is much more flexible.

Accompanying this sensitiveness is a pronounced rigidity of behavior so that we think of insect behavior in terms of tropisms and instincts. The insect's reactions to stimuli as compared with those of vertebrates are more direct, intense and invariable. The moth has to fly into the flame, the house fly has to come into the warm house in cool weather, the parasitic wasp has to find the host by smell. They have no choice, so that the insects have an inflexible behavior as compared with that of vertebrates. Neurologists and experimental zoologists have been explaining this inflexibility of insect behavior as due to its simple nervous system. This explanation is obvious and has to be granted but I wish, in this paper, to point out some factors in the insect's body structure that accentuate or actually exaggerate this sensitiveness and the accompanying rigidity of behavior.

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[3] Huber, L. L., and Neiswander, C. R. Paper before Amer. Assn. Ec. Entomologists, Dec. 1926.

I think of an insect as a physiological mechanism operated by various stimuli entering it through its sense organs while the intake of food and oxygen supply the power for this operation. Therefore the behavior of the insect is largely conditioned by the proportions of the various kinds of stimuli that reach the central nervous system; if dominated by light stimuli it will be heliotropic, if by chemical stimuli chemotropic, etc.

One general condition probably enters into all the types of sensitivity displayed in insect behavior. This is the extra sensitiveness due to the fact that the insect is a small animal. It appears to be a matter of the relation of surface to volume. Sense organs of one kind or another are well scattered over the surface of nearly all higher Metazoa. As the size of the animal decreases the ratio of surface to volume increases. The size of the central nervous system decreases in proportion to decrease in volume while the number of sensory cells decrease in proportion to surface so that there is a distinct tendency in small animals to have a proportionally greater number of stimulus receiving sense cells. The greater inflow of stimuli per unit of volume of the central nervous system tends to place the latter more positively under control of the stimuli entering and thus to condition a more rigid behavior. It would be difficult to actually prove this without counting the number of sense cells as compared with the total number of cells activated by them in the central nervous system, but small size is probably a real factor in increasing sensitiveness.

An evolutionary condition appears to enter into the problem also. The differentiation of sense receptors to specific stimuli and their elaboration into special sense organs was such a great step in advance in the evolution of the nervous system that it outran the evolution of compensating controls in the central nervous system in organisms of the evolutionary level of the insects. Sense organs were rather fully evolved before the necessity of controls appeared. This gave the type of insect organism that possessed great capacity for the reception of stimuli but poor means of controlling or using them after they had entered the nervous system. In later and higher evolution various inhibiting and controlling features were added to the central nervous system that freed the organism from the dominance of sensory stimuli, thus permitting the evolution of a more plastic behavior. This has happened even, in a small way, in the higher insects such as social forms where plasticity of behavior appears. The inhibition and control of stimuli has reached its greatest development in the brain of man where nearly all stimuli are more or less under memory control.

Sensitiveness to moisture.—Insects are very closely tuned to narrow moisture limits in their environment because they are at a great disadvantage as compared with larger animals, such as the vertebrates, in the ratio of their surface to their volume. Their surface is so great as compared to their volume that they dry out more rapidly than do larger animals. This ratio favors the larger animals because the volume increases as the cube of the diameter while the surface increases as the square of the diameter. To an animal as small as an insect, which has such a large surface that dissipates moisture in proportion to the small volume that furnishes it, this matter of moisture losses becomes a very serious problem.

The difference in this matter between such a large insect as a silk-worm and as small a vertebrate as a rat is astonishing. If we assume both to be simple cylinders, for mathematical simplicity, the silk-worm to be 2 inches long by ¼ inch in diameter, and the rat to be 6 inches long by 2 inches in diameter, and if both dissipated moisture with equal speed from equal areas of their surfaces, the insect would dissipate about nine times as much moisture per unit of volume as does the rat. This is a tremendous disadvantage for the insect which, while it is compensated for somewhat by the nearly impervious exoskeleton, has to be offset in various ways before the insect can occupy any even moderately dry environment. The most outstanding adaptation to equalize the insect's chances in spite of its small size is its sensitiveness or discomfort when its minimum limit of surrounding humidity is approached. The insect becomes active until it accidentally comes into surroundings of greater comfort with increased humidity. The sensitiveness saves the individual insect.

However it does not always save the species, as a series of dry seasons may lower the humidity enough to reduce the numbers of a species very materially. Cook's[4] work on the Pale Western Cutworm has shown how series of dry years may change the distribution for hundreds of miles.

Many species are saved to dry environments by various tricks of habit and structure. In the desert and in the semi-desert or great plains, we find, first, that the great majority of insects are active only during the early spring when winter rains have increased the humidity while they aestivate in some more impervious form during the hotter and dryer parts of the year. This phenomenon has been attributed to the abundance of herbaceous food in the spring but is probably as much due to the increased humidity of that season. It is at that time that the leaf-hoppers and smaller insects are abundant. Second, a large number of desert insects are nocturnal. Bradley[5] found that a tent light would be covered with swarms of insects in deserts that harbored very few diurnal forms. Such species avoided the dry daylight air by hiding in the ground or by lowering their respiration by inactivity during the day but swarmed out at night when the lowered temperature raised the humidity. This is true also of prairie insects where humidity is low because of lack of shade. Here we find the thin skinned larvæ of various groups nocturnal, those of the Crambidae, Noctuidae and Hesperoidea especially. Third, many insects have become subterranean and thus avoid desiccation, such as the desert coccid, Margarodes[6] and various aphids, fulgorids and cercopids.[7] The desert ants dig deeper nests than do their relatives of the humid regions as has been pointed out by Wheeler[8] for the fungus-eating Atti. Fourth, certain groups of minute insects have few desert representatives though otherwise they would be expected to occur in such regions. This is particularly true of Mallophaga[9] which are seldom, if ever, found on desert birds while they are abundant on nearly every waterfowl. Fifth, many insects have developed impervious stages for long-period aestivation until favorable moisture conditions recur again. The coccid, Margarodes, has evolved a hardshelled quiescent stage, the so-called desert pearl, between the larva and the adult in which it can aestivate several years. The bombycine moth, Rothschildia,[10] has an impervious pupa or perhaps cocoon in which it has been known to aestivate as long as eight years, the individuals of the brood emerging at irregular intervals during this time when some of them strike a humid season. Sixth, the characteristic day insects of the hot deserts are usually large forms such as Acridid grasshoppers, Tenebrionid beetles and cicadas, where the ratio of surface to volume is not so disproportionate. The Odonata of the desert that fly any distance from the few humid stream valleys are large insects. The small Zygoptera stay close to the marshy spots. Curiously enough we find that the aquatic insects of the desert streams are usually specific desert species[11] so that the limits of aridity must condition the adult, as the conditions for the larvæ are the same as for larvæ of aquatic insects in mesophytic regions.

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[4] Cook, W. C. 1926. Ecology, VII. pp. 37–47.

[5] Bradley, J. Chester. 1919. Sci. Monthly, VIII, p. 362 and statements to the author by Harry Knight.

[6] Ferris, G. F. 1919. Ent. News, XXX, pp. 27–28.

[7] Ball, E. D. 1901. Ohio Nat. I, p. 122. 1909. Proc. Biol. Soc. Wash. XXII, pp. 197–204. 1915. Ann. Ent. Soc. Amer. VIII, pp. 365–368.

[8] Wheeler, W. M. 1923. Social Life Among the Insects, p. 194.

[9] David Hall, while collecting Mallophaga in Utah, found none on birds of the open desert. 1925.

This sensitiveness to the amount of humidity runs all through the insect fauna of the mesophytic regions also. Even in these regions the number of species on the wing is greatest in May, June and the latter part of August and not during July, when light and temperature are highest and one would expect the greatest amount of activity in cold-blooded organisms. The larvæ of the August peak may be present in July but larvæ are usually in situations more humid than those the free flying adult can occupy. The lowered humidity of mid-summer, because of the increased heat, thus appears to be a seasonal barrier to the appearance of many species.

The writer has discussed this phenomenon of two peaks of occurrence during the collecting season with various men of wide experience in collecting but no one has been able to offer a satisfactory explanation of it. The usual feeling is that it is due to a two peaked coincidence of several causes, abundance of food plant, length of life-history, etc. Starting with the work of Shelford and Adams[12] on the great differences of humidity within relatively short distances in any general environment, we have come to recognize that this is probably one of the most important factors in the distribution of most insects. This assumption has been recently confirmed by the work of Transeau[13] and his students on the distribution of insect pests in Ohio. While these may be widely distributed, they seldom occur in numbers great enough to cause damage (in an optimum condition of existence) except in areas that follow very closely the distribution of the types of forest mapped for Ohio.[14] Plant ecologists have correllated the distribution of forest types very closely with humidity, from which we infer that the same factor probably controls the distribution of insects limited to the same areas, especially as the food plants of these insects are much more widely distributed but are practically undisturbed outside these narrow limits of humidity. If this is true, then the differences in humidity in any given environment are as great between the mid-summer and late spring on the one hand and fall on the other as between an oak-hickory association and a beech-maple or a mixed mesophytic association. This is enough of a difference to account for the two peaks of abundance of species of insects during the season.

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[10] Rowley, R. R. 1923. Note, Can. Ent. LV, p. 198.

[11] The writer has found this true in Odonata, but it is true in other groups.

We find that even in the mesophytic regions of relatively high humidity the minute insects, which are extraordinarily handicapped by ratio of surface to volume, are usually found in exceptionally moist situations. The moist soil is full of minute Collembola and dipterous larvæ. In fact the thin-skinned larvæ of nearly all small Diptera either are aquatic or live in very moist conditions. Outbreaks of aphids with their small size and thin chitin are usually looked for by economic entomologists during periods of humid weather. A short dry spell will completely clean up outbreaks of potato aphis.[15] The larvæ of some insects are never found except on the under surfaces of leaves where they can exist in the delicate stratum of humid air covering the respiratory surface of the leaf.[16]

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[12] Adams, C. C. 1915. Ill. State Lab. of Nat. Hist. Bull. XI, pp. 33–280.

[13] Huber, L. L., and Neiswander, C. R. 1926. Paper before Amer. Assn. Ec. Entomologists, Dec., 1926.

[14] Transeau, E. A. 1926. Paper before Ecological Soc. of Amer., Dec., 1926.

[15] C. R. Crosby to the writer concerning potato aphis on Long Island.

[16] Cutright, C. R. 1923. Jour. Ec. Ent. XVI, pp. 448–456.

The few dipterous maggots, such as Syrphid larvæ, that crawl about in exposed situations are thicker skinned than ordinary maggots and usually live in colonies of aphids which themselves occupy relatively humid surroundings. Small insects, such as Coccidae, that do live in exposed situations are usually specially adapted to these by burrowing in bark as in Xylococcus, by waxy coverings as in diaspine scales or by specially thickened body walls as in Lecanium. The latter are two separate and distinct adaptations in the same family that offset the disadvantage of ratio of surface to volume in such small insects. The many small insects that manage to live in comparatively exposed and dry situations are usually sucking insects (hemipterous) which can supply moisture dissipated in the low humidity by the constant intake of plant or animal juices. This applies especially to the numerous small Homoptera which are also well protected by a relatively thick chitinous body-wall.

The sensitiveness of small insects to amount of humidity is evidenced further by the negative evidence that all ponds and streams fairly teem with myriads of minute insects. Here they are freed from the conditions imposed by small size. Here we find the innumerable hosts of Chironomidae, Psychodidae, minute Trichoptera, Ephemerida and small Plecoptera. Futhermore, the adults of nearly all of these are nocturnal which brings the activity of the small adults into the time of day of greatest humidity. Miss Annette Braun's work on the Microlepidoptera has shown the same conditions for these minute insects. The larvæ are miners that live in moist plant tissue while the adults are nearly all crepuscular. There may enter here another factor, which will be discussed in a later paper, that of the actual crowding of these primitive types into areas and times of low metabolic activity by more modern and more active species. As an aquatic environment is no handicap to a large insect, in the matter of ratio of surface to volume, many of these are found in the water also.

The small size of the insect thus imposes on it the problem of moisture balance between its exterior and interior as the ratio of evaporating surface to the volume that supplies the moisture becomes more disadvantageous as the size of the organism diminishes.

It has been suggested to the writer that the tracheal system aggravates this situation as it penetrates all tissues and must constantly withdraw moisture. But on further consideration it does not appear that this adds any more of a handicap than does lung respiration to the larger land vertebrates, because equal respiratory surfaces, whether on a tracheole or on a lung epithelium, probably dissipate about equal amounts of moisture with equal activity of the tissues involved in oxidation. This can favor a land vertebrate only if more oxygen and less accompanying moisture can pass through a lung surface than through a tracheole wall, a point on which we have but few data.[17]

Sensitiveness to Temperature.—Insects are very sensitive to relative temperatures. The work of Shapley[18] on the ant Liometopum and of Miller and Gans[19] on Cremastogaster shows this very strikingly. Unfortunately most of the work on heat reactions of insects has been done on eyed species where the reactions to light have not been positively eliminated. Hence work, like the above, on blind worker ants gives us more reliable data. Each species of insect has a fairly definite point at which it becomes active on rising temperature or inactive on a descending temperature. This is the handicap of every cold-blooded animal. The warm-blooded vertebrates ignore the lesser changes in temperature.

This condition in insects is based on the relation of surface to volume as was the problem of desiccation. Small size prevents the animal from keeping warm by heat generated within itself. This problem is nicely stated by Haldane.[20] "All warm-blooded animals at rest lose the same amount of heat from a unit area of skin, for which purpose they need a food supply proportional to their surface and not to their weight. Five thousand mice weigh as much as a man. Their surface and food, or oxygen consumption, are about seventeen times that of a man. In fact a mouse eats about one quarter its own weight of food every day, which is mainly used in keeping it warm" If we consider an insect proportionally as much smaller than a mouse as a mouse is than man, the amount the insect will have to eat to keep warm will work out as follows:

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[17] Bayliss. 1915. Principles of General Physiology. pp. 628–629.

[18] Shapley, Harlow. 1920. Proc. Nat. Acad. Sci. VI. pp. 204–211.

[19] Miller and Gans. 1925. Jour. Comp. Psychology V. pp. 465–473.

[20] Haldane, J. B. S. 1926. Harper's Magazine, March, p. 426.

The man would use food equal to one percent of his weight and the mouse the equal to twenty five percent of its weight while the insect would eat an amount equal to six hundred and twenty five percent of its weight. This would appear to be an alimentary impossibility though some slight compensation may occur in the early and late flying social insects that fly from early dawn till full darkness such as Vespa and Bremus through the concentrated and easily digestible nature of their foods that may give them enough body warmth to extend the hours of their activity. Because of the great amount of food that would be neccessary to keep the body warm, all insects are compelled to be cold-blooded which makes them exceedingly sensitive to the surrounding temperature. A few social insects such as Apis and Vespa have nests with walls of some non-conducting material that conserve the heat in their brood nurseries. A nest of Vespa is as warm as blood and is held to that temperature night and day during the brood season.

A cold-blooded existence is a tremendous handicap as it prevents activity during cold weather so that in cold regions insects lose half of their time in some manner of dormancy and are exposed during this time to the vicissitudes of unfavorable weather that each year reduce their numbers to a very low level. A warm-blooded animal is practically indifferent to moderate changes in temperature but an insect enjoys full activity only in a specific and relatively high temperature. Thus through the ratio of surface to volume insects are conditioned by their small size to sensitiveness to temperature.

This phenomenon of exact adjustment of insects to specific temperatures is so well known to entomologists that it needs little argument. However much care has to be taken in field observations on reactions of eyed insects to temperature unless checked by controlled laboratory experiments, as in Chapman's[21] interesting work on sandune insects. Here he found that each species was rather closely tuned to a specific level of temperature, below which it became inactive and above which it died, so that species after species became active as the morning temperature arose and in the afternoon became inactive in inverse series as the temperature fell. A student of mine,

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[21] Chapman, R. N. 1926. Animal Ecology with Especial Reference to Insects. Part II. pp. 158–170. Minneapolis.

Mr. R. A. Hefner, found the same thing true this summer at Put-in-Bay, for insects visiting the flowers of Ceonothus.

An interesting feature of this "entomological clock", as Chapman has named it, is that the social species of Vespa, Polistes, Bremus and Apis work earlier and later in lower temperatures than do the non-social species which are largely active only during the heat of the day. The social species are attuned to hard work and long hours by the many mouths to feed at home. R. C. L. Perkins has told the writer that certain English bumble bees work all night on warm moon-light nights in June. *Vespa maculata*, to my own sad experience when collecting nests, returns home when it has become so dark that these wasps cannot be seen by the human eye but can be only heard and felt! The fact that in the temperate regions we have no very small social wasps and very small social bees such as are numerous in the tropics may be due to the necessity of moderate or large size in a social insect in order that it can fly early and late. Perhaps having to work long hours in cool mornings and evenings to feed brood prevents small species, with great disadvantage of relatively large radiating surface as compared to food intake, from entering the cooler regions. By some, at present unknown, compensation, the ants have made adjustments of small size to this social pressure. The small Halictids,[22] have been shown recently to be social but do not carry the great brood responsibility found in the more social species.

On the other hand insects are somewhat negatively thermotropic to temperatures too high for comfort. This is accentuated by the condition that few insects can cover the body surface with moisture, which by evaporation would reduce body temperatures in situations of too intense heat. The sweat glands in mammals serve this function but only a few insects, such as cercopid larvæ and the Pear Slug, have means to moisten the surface of the body and thus reduce the body temperature. Curiously enough both these insects are able to occupy rather exposed situations in spite of their very thin-skinned bodies. True also, the exudation probably serves as well for protection against desiccation and against enemies as to keep the insect cool. Apparently only insects that have immediately available large sources of plant juices can do this. We have few records in the literature of negative thermotropism in insects under natural conditions as few environments become too warm for their maximum activity. Chapman[23] has shown such conditions in sand-dune situations and the writer[24] has observed what was interpreted as such in Odonata. The ratio of surface to volume works favorably here, as many insects can live in temperatures that would be soon injurious to many mammals. Because of the relatively great surface for radiation in animals as small as insects, the heat of metabolism is radiated so rapidly that it does not accumulate to a dangerous degree in unusually warm situations.

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[22] Stockert, E. 1923. Knowia II. pp. 48–64, 146–165, 216–247. (Since the above was put in type Dr. E. F. Philips has suggested to the writer that because flying insects have to operate at higher speed than walking insects the small ants are able to operate at lower body temperature than the small wasps and small bees.)

Insects are thus small cold-blooded animals, so small that the radiating surface is out of all proportion to the volume of tissue supplying heat and so cannot oxydize food fast enough to keep the body at a regulated temperature-level high enough for continous high speed activity. Apparently, as shown previously, not enough food can be eaten for heat producing oxydation to offset the constant drain through the proportionally great radiating surface. Thus insects have become highly sensitive to changes in temperature which gives them the ability to recognize situations where there is the least difference between internal and external temperatures. They thus are thermotropic and can find situations where this loss by radiation is equalized.

In the two responses just discussed, that to moisture and that to temperature, the relation of surface to volume as involved in small size is the structural factor that has conditioned the sensitiveness of insects to these stimuli. In the two responses to be discussed, that to light and that to odors, the factors that condition sensitiveness are in the structure of the sense organs themselves, as I shall show.

Sensitiveness to Light.—Most insects with compound eyes, which includes larvæ and adults in the Exopterygota and adults only in the Endopterygota, are astonishingly sensitive to light. As pointed out in the introduction certain species of stone-flies are attracted to a seventy five watt light a half mile away and undoubtedly many other insects are equally sensitive. Many nocturnal insects are so sensitive to light that they are thrown into a state of catalepsy in strong light by overstimulation. This overstimulation accounts for the inactivity of many crepuscular and nocturnal insects in broad day light. This occurs in May-flies. This past summer during the swarming of Hexagenia at Put-in-Bay, Ohio, these insects hung motionless during the day everywhere about the grounds and many entered the laboratories and dormitories. As the light intensity decreased at twilight, they became active but in the houses became inactive again when the electric lights were turned on. One evening in a game of bridge the lights went out. A single candle was procured so the rubber could be finished. Some two dozen Hexagenias that had been hanging motionless on the walls of the room under the glare of the seventy five watt Mazda light immediately relaxed, became fully active and flew down to the single candle on the bridge table. Until the over stimulation of the electric light had been removed the may-flies had been sitting with their front legs held rigidly in front and their cerci cocked up as rigidly behind. They had been rendered rigid by over stimulation from the Mazda light.[25] This is probably, as stated above, the condition in most nocturnal, eyed insects, though moisture and temperature are conditioning factors also.

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[23] Chapman, R. N. 1926. Ecology VII. pp. 416–426.

[24] Kennedy, C. H. 1925. Biol. Bull. XLVIII, pp. 390–401.

The structural defect of the compound eye that appears to condition this overstimulation to the point of catelepsy is the great size of the compound has eye in proportion to that of the nervous system. The compound eye has to possess a certain specific size before it can give a distinct image. This is because the image, as shown by Exner,[26] is ordinarily mosaic so that the greater the number of facets the finer the mosaic of light on the retina giving thus an image more distinct and sharp in detail. But even in the largest insect eyes the image is vague, as was shown by Exner who placed a photographic plate in the place of the retina and used the compound lenses as a lens for this experimental camera. Photographs of objects thus

[25] Schmidt, P. 1919. Smiths. Rept. for 1917, pp. 501–505. Schmidt discusses "Catalepsy in Phasmidæ," and notes that it is activated from the anterior end of the insect, but does not suspect light stimulation.

[26] Exner. 1891. Physiologie der Fazettierten Augen, etc. Vienna.

obtained were hazy as though seen through a heavy fog. Dr. H. Eltringham[27] has recently made better photographs in the same manner but these are not sharp in detail. A compound eye a foot in diameter containing millions of facets would probably give an image that would compare favorably in distinctness of detail with the image in the vertebrate eye. Thus the smaller the eye and fewer the facets the coarser the mosaic of light and the more vague the image.[28] To offset this structural defect of mosaic vision the compound eye has to be as large as the insect's nervous system can operate. In insects with more acute vision, such as Odonata, Pipunculidae and male tabanid flies, the greater part of the anterior end of the insect is eye.

The structure of the mosaic retina itself accentuates the coarseness of the moasic image thus increasing the vagueness of details. Each light sensitive rhabdom is a composite of seven retinal cells so that there is but one light sensitive point to each seven cells of the retina. The field of acute vision in the vertebrate eye, on the other hand, is composed almost entirely of individual cone cells, each of which is a light sensitive point. If retinal cells are of the same order of size in the retinas of insects and vertebrates, the vertebrate retina would give a vision seven times as distinct in detail.

The great relative size of the eye does several things to the behavior of insects. First, it tends to crowd out the other distance senses, those of hearing and smell, because of the small size of the insect which is a perfect mechanism in which there are no reserves or excess tissues, no connective tissue, a body wall of a single layer of cells, no vascular system, etc. The insect is so small that to operate successfully, every tissue and organ has to run to capacity. Any excessive development of one function withdraws physiological support from some other organ. Thus in flying predators as in Odonata sight is the most valuable sense so it has been developed to the injury of the antennae and the sense of smell. The same is true of may-flies, though here some other sense would undoubtedly be equally valuable as is shown in the ecologically parallel Chironomidae which have almost the same habits of flight and mating but which possess well developed antennal senses but only mediocre eyes. When the eyes are so large, they draw on the nervous system for such a great amount of power to operate that other senses have to be given up. We have not usually thought of sensory cells as using much power because their fatigue does not come into consciousness but probably they use as much power per cell as do motor cells, which in the case of the compound eyes with optic tracts whose cross-sections are greater than that of any other nerve of the body must be a tremendous drain on the nervous system. Recent physiological studies[29] have shown that nervous tissue has the highest oxydation rate of any tissue of the body. Thus as in may-flies and Odonata the insect's sensitiveness to light is increased through indirection by the reduction or even elimination of other senses.

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[27] Eltringham, H. 1919. Trans. Ent. Soc. London.

[28] Haldane, J. B. S. 1926. Harper's Magazine, March, p. 426.

Second, the great relative size of the eyes makes the insect directly hypersensitive to light. This is due to the proportionally enormous stimulation that must pour into the nervous system through the very large eyes. All insects with compound eyes are notoriously heliotropic, positively or negatively. They are so overstimulated by light that they are held to this rigid heliotropism, as cited previously for the may-flies at Put-in-Bay. The situation is quite different in the vertebrate, where the retinal surface which receives light stimuli is relatively small in comparison to the areas devoted to the reception of other stimuli and is proportionally very much smaller in comparison to the very large central nervous system that is activated by the stimuli. The behavior or reaction of the animal is an integration of various stimuli or a balance of one against another. With the enormous area of retina in compound eyes which may cover nearly the whole surface of the head, the flood of stimulation entering the nervous system through the eye overbalances every other stimulus and activity of the nervous system simply because the mosaic eye has to be large to give a relatively distinct image. If the vertebrate eye covered the whole head we would likewise be positively and rigidly heliotropic. The vertebrate retina is so small in comparison to the amount of nervous system to be stimulated that in vertebrates this is seldom overstimulated by light. Thus, while the sight in vertebrates is adequate to give distinct vision it seldom overstimulates the general nervous system which can develop more easily those delicate and precise reactions to the stimuli entering that condition more plastic behavior. Any one who has tried to write in a flood of light and noise can understand the effect on the internal reactions of the insect's nervous system when swamped in light stimuli. This overstimulation is compensated for in all manner of ways in insects, by pigment, by degeneration of eyes in larvæ and in forms where the sense of smell is adequate, and by movements into or out of light. However the fact remains that the insect with compound eyes large enough to form distinct images is over-eyed and over-stimulated by light, hence hypersensitive to light.

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[29] Parker, G. H. and students in recent papers.

For an animal with little psychic sensitiveness the usual eyed insect is very sensitive to objects in motion.[30] This sensitiveness appears to come from the fact that an object moving across the field of vision strikes each facet in succession, delivering a series of discrete stimuli to the nervous system. A moving object for the same reason is more visible in the vertebrate eye than a stationary object, but in the compound eye the series of stimuli from a moving object are fewer in number and are farther apart in time and space and so are more effective than in the vertebrate camera eye. Vertebrate sensitivity to moving objects is probably more often accentuated by psychic responses such as fear, anger, hunger, sex, etc. One who has collected Odonata, soon learns how exceedingly sensitive these insects are to motion of the collector but how apathetic they are to him when he is stationary.

The work of Forel[31] and more recently of Lutz[32] has shown us that insects are probably more sensitive to ultraviolet rays than to the series of rays forming the spectrum visible to the vertebrate eye. No work has been done experimentally yet to determine whether this difference is due to the quality of light after passing through chitinous lenses or to a different sensitivity of the nervous light receptors. Some simple experiments with insect lenses ought to determine this. If due to the transmitting quality of the chitinous lenses, this peculiarity of sensitiveness to ultraviolet rays would fall in our category of non-nervous factors that condition the sensitivity of insects.

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[30] Imms. 1924. General Textbook of Entomology, p. 78.

[31] Forel. 1908. The Senses of Insects.

[32] Lutz, F. E. 1924. Ann. N. Y. Acad. Sci. XXIX, pp. 471–528.

Insects are thus conditioned to great sensitivity to light because of their small size and mosaic vision. The mosaic eye has to be large in proportion to the small nervous system to give a vision distinct enough to be useful. This increases relative sensitiveness to light as the large eyes crowd out other sense organs through physiological competition and increases specific sensitiveness to light by flooding the small nervous system with light stimuli.

Sensitiveness to odors.—In the sense of smell many insects are superior to vertebrates. When we realize that some moths can smell their mates a mile away[33] and that among social insects friends are recoginized by odor, we get some conception of the world of odors in which many insects live. This sense has been especially developed in insects that are blind or that have poor eyesight, as in termites and worker ants. In these the more delicate sense of smell is not overbalanced by a flood of light stimuli.

There is much doubt among experimentalists as to just how an insect detects odors. The various types of supposed organs of smell are reviewed by Snodgrass.[34] The sense of smell has been variously attributed to three types of organs, (1) hair organs divided into sensilla basiconica, sensilla coelonica and sensilla ampulacea, (2) campaniform organs and (3) plate organs, all of which appear to have been derived from simple tactile hairs. The usual theory is that the more important chemoreceptors are on the antennae, but McIndoo,[35] who has done much work on insect sense organs, believes that the sense of smell is located in certain groups of sensilla on the bases of the wings and the legs. The writer does not believe that there is enough clear experimental evidence against the older theory of an antennal sense of smell to discard it yet.[36] Undoubtedly organs of smell do occur on other parts of the body also. The writer wishes to be more or less noncommittal until the experimentalists have settled the question definitely. The fact that some insects (male honey bees) have on the antennae as high as 30,000 sensilla placodea (plate organs), the structure of which suggests a function as chemoreceptors will have to be explained before we can abandon the theory that the antennae are organs of smell.

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[33] Recent unpublished experimental work shows marked moths attracted a mile by chemical baits.

[34] Snodgrass, R. E. 1926. Smiths. Misc. Coll. LXXVII, No. 8.

[35] McIndoo, N. E. 1914. Smiths. Misc. Coll. LXIII, No. 8. 1922. Smiths. Rept. for 1920, pp. 461-484.

[36] Hauser, Gustav. 1880. Zeitsch. f. wiss. Zool. XXXIV, pp. 367-403.

However, if we follow Hauser and Forel in assuming that the antennae are the main organs of smell, certain features of their structure would help to account for the unusual development of this sense in insects. First, the antennal chemoreceptors have a relatively dry receiving surface while the sensory parts are thoroughly protected from drying by chitin which permits their exposure on the outer surface of the animal. Second, they are elevated on movable organs (the antennae) which places them in a very advantageous position for investigating odors.

The supposed chemoreceptors appear to have been derived from tactile hairs by the reduction of the hair to a thin-walled cone (hair organ), a thin-walled bell-shaped structure (campaniform organ) or to a delicate, plate-like chitinous (?) membrane (plate organs). Many stages of this evolution of chemoreceptors have been described in various insects. When we check over the limitations of this type of organ we find that the fairly dry, chitinous receptive surface imposes the defect shown by many insects of being relatively insensitive to odors in dry weather. Parasitic Hymenoptera, in the writer's own experience, can hardly be attracted to baits in dry weather while they come in large numbers in humid seasons. However such behavior might be interpreted as sensitiveness to lack of humidity.

The relatively dry receiving surface of the chemoreceptors, on the other hand, has made an organ that can be placed externally and so is more effective in locating odors than an organ placed internally as in land vertebrates.

Furthermore, the sense of smell has profited greatly by the elevation of the chemoreceptors on an external movable organ, the antenna.[37] The tubular chitinous antenna makes possible the elevation of the sensilla from the surface of the body in an organ that can be directed or placed in the most advantageous position for examining odors. Forel has pointed out the possibilities of increased discrimination open to an insect because the organs of smell are located externally on antennae which can be waved about in the air studying each odor, as it were, *in situ*, rather than having to distinguish odors after they had been thoroughly mixed and stirred about by being drawn into an olfactory chamber, as in land vertebrates. Forel even goes so far as to suggest that higher insects, such as ants, may have a memory for odor-forms of objects after having touched them all over with the antennae, a type of memory incomprehensible to a visual minded human being with a degenerate sense of smell.

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[37] Forel. 1908. The Senses of Insects.

The richness of possible reactions through chemotropism appears to have been overlooked by most writers on tropisms. It is usually classified in the same category as hydrotropism, thermotropism, heliotropism etc, whereas in point of richness of diverse chemostimuli it is in a class by itself. The range of possible stimuli in either hydrotropism, thermotropism or even of heliotropism is very small as compared to the possible range of stimuli in chemotropism. Heliotropism does become rich in possible reactions in the higher vertebrates through the evolution of an intricate brain to interpret retinal images but in organisms of the evolutionary level of insects this ability is undeveloped. In insects the number of possible chemical stimuli appears to almost infinite while in each of the other tropisms the range of possible stimuli is comparatively narrow. This puts chemotropism in an order of richness of possible reaction far above that of any other tropism, in fact, in a class by itself. This richness of kinds of odor stimuli is probably the quality which has made reaction to chemostimuli of such great value in the life of social insects which are the last and highest evolutionary insect type. Chemotropism thus appears to have been of greater value in insect evolution as the social integrant than any of the other tropisms with lesser ranges of possibilities.

We have so few data on the sense of touch in insects that it is hardly worth our while to review it.[38] Probably nearly all the movable hairs are tactile organs and some of the free nerve endings in the hypodermis may have a touch function. Apparently the hard chitinous nature of the tactile organs prevents the insect from getting any touch impression of an object other than that of its mere presence or absence. Texture of surface of the object, its hardness, etc., probably can not be perceived. Touch may be actually lacking over large areas of smooth, hairless, hard shelled insects such as beetles and some Hymenoptera. However, it is a valuable sense in the smaller adjustments of the insect to its environment and is made use of by the thigmatropic species such as Blattidae, Aradidae, and such as hide in crevices because they are not comfortable unless both dorsal and ventral surfaces are in contact by touch with the surroundings.

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[38] McIndoo, N. E. 1922. Smiths. Rept. for 1920, pp. 461-484.

The sense of hearing is very poorly developed.[39] Probably nearly all insects hear jars that are heavy enough to shake the whole organism but few probably hear any extended range of high pitched sounds such as those audible to the vertebrate ear. A small range of sound is probably audible to Johnson's organ in the second antennal joint, to Siebold's organ[40] in the tibia of Tettigoniidae and to the tympanal organ of Acrididae. The same is probably true of the sense of taste. Chemoreceptors are found on all the mouth parts and may function as organs of taste but experimental data are hard to obtain on these functions.[41]

The writer will show in another paper how nearly all conditions of insect sensitivity discussed above are imposed by the possession of an exoskeleton. This has limited the insect to small size and has made it sensitive to temperature and moisture because of the relation of surface to volume. The exoskeleton has conditioned a compound eye with mosaic vision and has made possible the development of external sensilla of smell and the development of movable antennae.

It has usually been assumed that the sensitivity of any organism to stimuli is a direct function of the nervous system.

In this review of the sensitivity of insects the author has attempted to show that, while the final sensitivity is a function of the nervous system, it is conditioned by various other structural features of the organism in question. The small size of the insect has conditioned the sensitivity to moisture and temperature. The chitinous exoskeleton has conditioned sensitivity to odors and to light while it has conditioned the quality of the sense of touch.

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[39] Forel. 1908. The Senses of Insects.

[40] Schwabe, Josef. 1906. Zoologica. L, pp. 1-154.

[41] McIndoo, N. E. 1916. Smiths. Misc. Coll. LXV, No. 14. 1922. Smiths. Rept. for 1920. pp. 461-484.

THE ROCKY MOUNTAIN SPECIES OF THE MAYFLY GENUS EPHEMERELLA.

JAMES G. NEEDHAM.

Ever since the publication in 1884 of that part of Eaton's *Revisional Monograph of Recent Ephemeridæ* treating of the genus Ephemerella, the Rocky Moutain region has been known as the source of some of the most remarkable of Mayflies. The strangest of these Eaton knew only as nymphs. These he described and figured. The incomplete results of rearings that were published by myself in 1905 and by Dodds in 1923 left matters in some confusion, as was pointed out by Lestage in his comprehensive review of the group in 1925. For some time there has been obvious need of more careful life-history work on these forms, such as could only be done in the place where they live.

In the summer of 1926 I had an opportunity, during a six weeks stay in Northern Utah, to live beside Logan River, and to rear many of the aquatic insects of that beautiful mountain stream. There I reared four of Eaton's species belonging to the Ephemerella group; and on a concluding trip to mountain streams farther southward I collected others as nymphs. For the first time material is at hand adequate for learning the identity of these curiously diverse forms.

In this group it is easy to find striking differences among the nymphs, while the corresponding differences among the adults seem trivial, and hardly of generic value. In this paper I shall treat Ephemerella as a single genus, having four subgenera in the Rocky Mountain region.* The seven species that I have obtained thence divide into four groups as follows:

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* This omits Chitonophora Bengtsson (1909) and Torleya Lestage (1917), because I cannot fit the American species to the combination of characters given in the definition of these very minor groups. It may be worthy of record here that Ephemerella nymphs of the Torleya type as described by Lestage, having compact bodies and stout, bristle-whorled tails, occur also in America. I have some specimens that were collected in 1923, in San Antonio Canyon, near Claremont, California, by Miss Theresa M. Robinson.

Key to the Subgenera of Ephemerella.

Adults.

1. Intercalary veinlets between veins Cu_2 and 1st A conjoined into two strong forks that are attached basally to the former........................2
These intercalaries weak and in part unattached basally...**Ephemerella** Walsh.
2. Veins Cu_2 and 1st A usually conjoined basally by a cross vein (sometimes touching at a single point); ♂, inner margin of long 2nd joint of forceps gently curved; ♀, 9th ventral segment bilobed at apex.....**Drunella** Ndm.
Veins Cu_2 and 1st A fused for a distance basally; ♂, inner margin of 2nd joint of forceps angulate; ♀, 9th ventral segment of abdomen entire at apex, **Eatonella** n. subg.

Nymphs.

1. Head with a broad frontal shelf..2
Head with no broad frontal shelf..3
2. Frontal shelf entire; body flat, hairy..................**Timpanoga** n. subg.
Frontal shelf notched at sides for reception of the antennæ; body plano-convex, smooth..**Eatonella**
3. Head with high dorsal spines or tubercles....................**Drunella** 4
Head with low dorsal spines or none........................**Ephemerella** 5
4. Mesothorax with no dorsal spines........................**E. grandis** Etn.
Mesothorax with high dorsal spines....................**E. spinifera** sp. n.
5. Front femora toothed on front edge.................**E. coloradensis** Dodds
Front femora not toothed on front edge...................................6
6. Gills on abdominal segments 3-7; 2nd joint of antenna black..**E. inermis** Etn.
Gills on abdominal segments 4-7; 2nd joint of antenna pale..**E. margarita** sp. n.

Ephemerella grandis Etn.

I especially desired to find and rear this species because of the doubt existing as to the identity of the nymph. So I was glad to find it common in Logan River. I reared thirteen specimens on eleven different dates ranging between June 18th and July 18th. Nine of these were males and four were females. About half of them are fully matured, finely colored specimens.

Neither imagos nor subimagos were seen at large.

It is the adult, rather than the nymph that is in need of completer description, since the male has not been made known, and Eaton's figures of the nymph leave, for that stage, little to be desired.

Adult male.—Length 14 mm.; tails 19–21 mm. additional.

Color of body dark brown above and below, phalerate with paler on most of the sutures. Abdomen conspicuously ringed with paler, and with pale lateral line, and a pale apical border across the 10th segment. Fore legs brownish, becoming paler towards the tip of the tarsi. Other legs all pale, except for a wash of brownish on femora beyond their bases. Tails blackish at base gradually becoming paler toward their long and very slender tips.

Body very stout. Wings hyaline, principal veins dark brown. Crossveins obsolete in the costal, subcostal and basal part of first radial spaces, heavy along the middle of the wing. Generally there is a crossvein joining the base of vein Cu_2 with the 1st anal vein, but occasionally a slight fusion of the two veins occurs at this point, eliminating the crossvein.

Abdomen slowly tapering. The ninth segment bears a short, sharply triangular lateral spine that is about as long as the forceps basis, and there is a trace of a spine in corresponding position on segment 8. The basal joint of the forceps is much wider than long; the second joint is long, smoothly curved and widened to both ends; the third joint is blunt, incurved and about a fourth as long as the second. The penes are unarmed, fused together, parallel sided, with a wide V–shaped apical notch between their apices.

The subimago is similar, but duller in coloration, and on the wings a bit darker owing to heavier pigmentation along the veins.

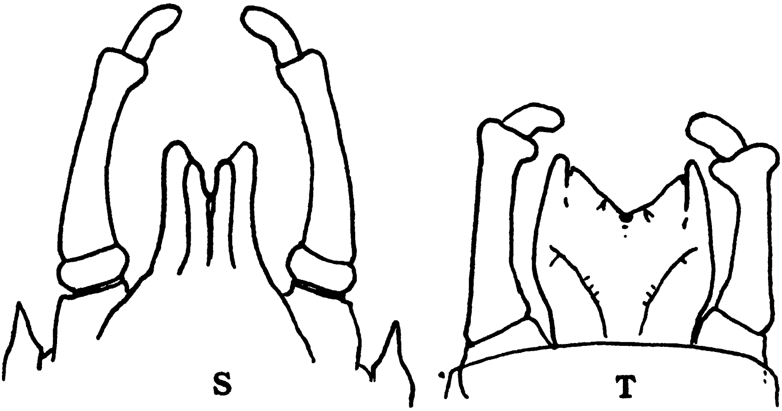

Fig. 1. Male genitalia: *S*, of *Ephemerella grandis*, and *T*, *of E, inermis*.

The statement in Eaton's description of the female, "Ventral lobe of segment 9 emarginate; the pleural points short and acute", leaves no doubt as to the identity of this species.

Eaton was right in considering the basal fusion of vein Cu_2 and 1st A in this species unusal (Monograph. p. 330) I was in error (1905, p. 43) in saying that he described it as characteristic of the species. I find that it occurs in but one of my adult specimens, and on one side only in that one. It was misleading that the single nymphal wing I then had for examination showed that fusion. However, when this fusion occurs, it is limited to a single point; whereas, in the species that Dodds (1923) reared and took to be *F, grandis*, the two veins coalesce for a short space.

The nymph of this species was adequately illustrated in Eaton's Monograph Pl. 38, Figs. 11 to 13. A few supplemental descriptive notes may be added here.

The length of grown specimens is 12.5 mm., with tails 7 mm. additional.

The coloration is usually obscured by the darkening of age and accretions of silt; but recently moulted specimens show an uneven pale middorsal line the entire length of the body, much widened on the 8th abdominal segment, and the lateral spines of the abdomen also pale. Legs broadly but obscurely ringed with brown, two rings on each femur and one on each tibia. Tails alternately brown and yellow at about six unequal intervals of each color; their joinings are sparsely beset with fragile, deciduous hairs.

The pale antennæ are shorter than the head is wide. Underneath the prothorax between the bases of the fore legs there is a flat hoof-shaped tubercle adjacent to the rear of the head. The dorsal tubercles are well developed. The stout pair on the top of the head has a backward slant. The rounded pair on the top of the prothorax has a smaller supplemental pair behind it, and the tubercle on each side of the prothorax has a smaller supplementary one before it. The paired, sharp, thorn-like, backward curving tubercles on abdominal segments 2 to 9 are longest on segments 8 and 9, but the length is increased gradually from segment 2 onward. The thin, flat, sharp lateral spines on segments 3 to 9 begin obscurely and increase in length to the 8th segment. On the narrowed 9th segment they are straghter, less incurved, but about as long as on the 9th. The 9th sternite is bilobed apically in the female; four-lobed in the male.

Besides the specimens from Logan River and those from Pecos, N. Mex., described by me in 1905, I have others from Santa Fe, N. Mex., collected by P. B. Paul and from Twin Lakes, Colorado, collected by Chancey Juday. Clemens records the occurrence of the genus in Ontario.

Ephemerella spinifera n. sp.

This is a smaller species than *D. grandis*, and with a much more remarkable development of spines upon the back. Only the nymph is known.

The nymph apparently grown measures in length 8 mm.; tails 5 mm. additional.

Color pale brownish with hardly a suggestion of pattern, though there is a succession of somewhat lighter areas on the tails. The head and body bear tubercles as follows: a huge pair on the top of the head, nearly doubling its height, aslant backwards; a smaller slender twin pair on each side of the pronotum; four pairs on the mesonotum, the median one of these largest, very prominent, aslant backward, two small sudmedian pairs, one at the front and one at the rear, the latter smallest and confluent, and outside the anterior pair is the fourth pair which is slender and of intermediate height. Then on the abdomen there are eight pairs, representing, the usual double line of dorsal hooks. These are on segments 2 to 9. They are all thorn-like, sharp-pointed and curved backward. They are subequal on segments 2 to 7, and on 8 and 9 they are three times as large and beset with scattered fragile bristles.

The pale antennæ are about as long as the head is wide. The front femora are swollen, widest across the basal third, carinate and broadly lobed in front, and carinate also above, where fringed with fragile setae. The "thumb" of the front tibia is two-fifths as long as the tarsus. There are flat lateral spines on abdominal segments 3 to 9, minute on 3 and gradually increasing in prominence to 7, 8 and 9. Gills on segments 3 to 7 in a regularly overlapping series.

Four nearly grown nymphs from Blackfoot River near Potomac, Montana, collected on June 20th, 1906 by Frank C. Barry, and a single younger nymph collected by myself in the north fork of Ogden River, Utah, on July 27th, 1926.

I have another nymph that will go in the subgenus Drunella, sent me by Chancey Juday, collected by him in the South Fork of the Keweah River, California, July 13, 1904

Ephemerella doddsii n. sp.

This is a species of large size that is known to some of the fishermen on Logan River as the "Ginger quill". In superficial appearance it is strikingly like *E. grandis*, despite remarkable differences in their nymphs.

Dodds reared a single specimen; and, finding in the wings a basal fusion of veins Cu_2 and 1st A, he naturally referred it to the only species in which that fusion was then known to occur, *E. grandis*. He published good figures of the nymph and of the gentalia of the male imago, and gave an excellent account of its habitat and habits.

The nymph is altogether unique in having developed out of the under side of the broad abdomen a powerful sucking disc by means of which it can stoutly adhere to the surface of smooth stones in the current. This disc adheres so firmly that a sudden pull on a leg will break the leg off before the disc will let go; but the nymph may be pushed about over a smooth surface without releasing the disc, and it probably creeps by means of the disc.

The species is common in Logan River. I reared fourteen specimens on five different dates between the 19th and 28th of June, and collected at large eight others as subimagos, two of which were reared to the full adult condition. The subimagos were all taken as they flew from the river at nightfall. No imagos were seen at large.

The adult measures in length of body, ♂, 13 mm., ♀, 14 mm.; tails, ♂, 11 mm., ♀, 14.5 mm. Fore leg, ♂, 12.5 mm., ♀, 8 mm. Fore wing, ♂, 14mm., ♀, 14.5 mm.

Adult male.—Coloration strikingly like that of the preceding species, brown, with paler sutures, giving a phalerate appearance to the sides of the thorax and a ringed appearance to the abdomen, whereon runs the same pale midlateral line and border around the apical margin of the last segment. The tails are notably shorter, but have the same dark bases and pale slender tips. The dark fore legs grow graually paler toward the tips of the tarsi, and the brown on middle and hind legs is less extended than in *E. grandis.*

The wings are similar except for a constant and more extended fusion of vein Cu_2 at base with the 1st anal vein.

The lateral spines at the apex of the 9th segment are much larger, and reach the level of the base of the 2nd segment of the forceps. Basal segments of the forceps as wide as long; 2nd segment constricted and bent, almost angled, in the middle; 3rd segment blunt, about a third as long as the second.

Adult female.—The female is much paler than the male but shows a similar color disposition on the sides of the body, legs, wings, and tails. Except at its ends the abdomen appears wholly dark, due to contained eggs. The entire top of the thorax is pale tan color.

On the lateral margin of the abdomen segment 8 is angled at the apex and 9 bears a sharply triangular lateral spine that extends backward as far as the apex of the 10th segment. The apex of the 9th sternite is produced beyond 10 into an oval, entire lobe.

The subimago is similar in appearance but paler of body and darker of wing, the veins of the wing being heavily shaded with fuscous.

The nymph measures in length 11.5 mm.; tails 4 mm. additional.

The nymph of this species, also, was adequately illustrated in Eaton's Monograph, plate 39, figs. 1-22. This species totally lacks dorsal spines. It is altogether unique in the broad frontal shelf on the head notched at the sides for the reception of the antennae and in the broad sucking disc that is developed beneath the abdomen.

The back is smooth, broadly rounded, the body being plano-convex. The color is yellowish or tan, darkening on the eyes, on the wings, on the gills, and the bases of tarsi and tails; also some pigment tends to overspread the middle of the terminal abdominal segments, but there is no definite color pattern.

Besides the specimens from Utah, I have nymphs that appear to be the same species from Potomac, Montana, collected by F. E. Barry; from Yellowstone Park, collected by R. Muttkowski; from South Fork of Keweah River, Califorina, collected by Chancey Juday; and from Goat Creek, Ashford, Washington collected by Miss Hortense Butler.

These two species, *E. grandis* and *E. doddsii*, form a remarkable pair. Here are two forms so alike in the adult stage as to be easily mistaken the one for the other, their nymphs totally unlike in appearance. The one nymph represents the highest development of spines upon back; the other, the extreme of smoothness. The one is black and dirty; the other, yellow and shining. The one clings by feet only; the other, by a highly developed ventral sucking disc.

The one lives in the edges of the stream, the other out in the swift current.

Ephemerella coloradensis Dodds.

This species was so adequately treated by Dodds (1923, p. 97, Pl. 8, Figs. 3 and 4, and 1924, p. 146,)* that I have only to add a few local notes. It is one of the commonest species in the rivers of Northern Utah, especially in their upland reaches, above 5,000 feet.

I have nymphs , also, from Yellowstone Park, Wyo., collected by Paul R. Needham; from Pecos, N. Mex., collected by Professor T. D. A. Cockerell; and from Volcano Co., Calif, collected by Chancey Juday.

On examining the stomachs of three native trout taken near the head of Logan River at about 7,000 feet, I found that this species made up about half of their food.

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* Dodds does not note that Eaton had already figured the nymph of this species in his Revisional Monograph (Plate 38, Figs. 1-10).

Ephemerella inermis Etn.

This species was very common in all the streams of Northern Utah, associated with the preceding one. I reared fourteen specimens on five different dates ranging from June 25th to July 29th, and have fully matured males and females that seem to agree well with Eaton's description of the adult. I present a figure of the genitalia of the male and a description of the nymph. This is Dodds' Ephemerella nymph No 2.

The grown nymph measures in length 9 mm.; tails 4 mm. additional. Color very variable; blackish, often reddish brown, sometimes with indications of a middorsal pale line. Pale specimens show extensive mottling of the dorsum in a complicated pattern of curved pale markings upon the brown of the thorax and of dots and dashes upon the abdomen. The antennæ are pale except for a black second segment and a slight darkening of their slender tips. Legs dark, with three obscure rings of paler on each of the principal segments. Tails obscurely marked in five or six alternating areas of brown and paler.

The head is without tubercles above and the front femora are smooth. The front tibia is prolonged at apex in only a very small rounded lobe. Under the claw are eight to ten close set teeth.

The abdomen has no dorsal tubercles or hooks, but in their place is a double row of pale dots, one pair on each segment. There are the usual thin flat lateral spines on segments 4 to 9, increasing in length and sharpness on 4 to 8, less pointed on the narrower ninth segment. The gills on segments 3 to 7 are regularly overlapping. The joints of the tails are ringed apically with a whorl of short spinules and thickly fringed with slender pale hairs.

I have nymphs of this species collected by John T. Needham in The Yellowstone Park, August 8th, 1921.

Ephemerella margarita n. sp.*

This pretty nymph I did not find in Logan River but it was common farther southward. I collected it in Box-Elder (Brigham) Canon, in Weber River at the Devil's Slide, at Wanship, and at several points along Provo River where it was most common, especially in the upper reaches of that stream. These places, being visited only at the time of my departure from Utah, I had no chance to rear it. Only the nymph is known.

It superficially resembles the nymph of the preceding species being of the same slender graceful form, but it lacks

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[1] Named for little Miss Margaret Hawley, of Salt Lake City.

gills on segment three of the abdomen, it has a single conspicuous cross band of black across the middle of the tails, its color pattern is different and its antennæ are wholly pale.

The fullgrown nymph measures in length 9.5 mm., and tails 2 mm. additional.

A slender prettily colored nymph with smooth thorax, and depressed, thin-margined abdomen. Color brownish olivaceous, with distinct blackish markings as follows: a median blackish spot on segments 2 and 3, another one on segments 5 and 6; a black streak across the apical margin of 8. Segment 9 wholly blackish above except its pale lateral spines and a pair of included submedian apical pale dots. Tails black and white; the black forming a bar across the middle and covering the tips, where it is less distinct. Legs pale, with dark bands on middle of tibiæ and tarsi and on tips of tarsi.

The head is smooth above. The front femur is entirely smooth. The front tibia bears no "thumb" but only a slight triangular prolongation beside the base of the tarsus. The claw is armed beneath with half a dozen slender teeth in a graduated series, the distal one longest.

The usual double row of dorsal hooks is represented by minute paired spinous tubercles. The lateral spines on abdominal segments 4 to 9 are thin flat, sharp and transparent, broadest on segment 7, where the abdomen too is broadest, and longest on segment 9. The gills are incompletely operculate.

This is the most generalized member of that group of species which has the gills beginning on the 4th abdominal segment with an operculate pair. The next following, *E. hecuba*, is the most specialized of that group. The two species occur together in Provo River.

Ephemerella hecuba Etn., (Hagen Ms.)

I much regret that I found this remarkable species only as I was leaving Utah and had no chance to rear it. The nymphs were grown and some of them fully ready for transformation as shown by the blackening wings. I found it only in Provo River where that stream washes the southern base of Mt. Timpanogas.*

Eaton's detailed figures of this species were made from a single cast skin. They adequarely represent structures. A few additional descriptive notes on color, made from whole nymphs, may now be added.

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* I have taken a liberty with the name of that magnificent mountain, abbreviating it to make a convenient and euphonious subgeneric name.

The full grown nymph measures in length 14 mm.; tails 6 mm. additional.

Under the general covering of silt that is held by the long soft hairs that everywhere clothe the dorsal surface a few markings of darker brown may be discerned, varying the general color of light brown or tan. Blackish rings cover the basal half of all the tarsi, and faint rings are on the middle of each tibia, with sometimes a suggestion of two more upon each femur. There is a broad band of black crossing the tails at two-thirds their length, and there are one or two very narrow black rings crossing them near the base; usually, one on the middle tail and two on each of the laterals. Eyes and wing cases become blackened toward maturity. The lateral spines of the abdomen show a pale area before their sharp brown tips.

On the smoothe flat ventral surface of the abdomen there are more or less distinct bands of brown crossing the basal half of the segments.

Numerous specimens were collected in the Provo River on the 20th of July by Dr. H. J. Pack and myself. They were found clinging to the waterworn cobble stones in the edges of the stream, and not out in the current. They are utterly helpless when dislodged from the stones. They do not attempt to swim but sprawl stiffly and if overturned bend the venter convexly upward displaying the brownish crossbars of the underside.

This is the nymph of which in 1905 I published a rather poor photographic figure that was copied by Lestage in 1925 (p. 236). It represents the extreme of flattening and widening of the abdomen and lengthening of lateral spines: but it does not deserve to stand apart from the others so far as in Lestage's key; for it is only a specialized member of that group of species to which *E. margarita* belongs—the group that lacks gills on abdominal segment 3, and that has a single band of blackish color across the middle of the tails.

I have a specimen of it that was collected for me by my son Paul R. Needham in the Lanier River, Yellowstone Park, Wyoming, on August 8th 1921.

I have a nymph of still another species of Ephemerella from the Rocky Mountain region. It has high dorsal hooks on the abdomen, like a Drunella, but has none on the head or thorax. I have but one specimen and that broken. It comes from Big Blackfoot River, Potomac, Montana, and was collected there by Frank E. Barry on June 29th 1906. The tails are lacking, and all but one (hind) leg. The paired dorsal hooks on abdominal segments 3 to 9 and very long and slender, adding about a third to the height of the abdomen. Their backwardly directed tips are sharp pointed. In front they stand erect, but gradually they incline backward until on segment 9 they point straight to the rear. The abdomen is marked with a heavy pattern of brown in three rows of large spots that lie upon the bases of the segments, one row mid-dorsal, and two lateral, largely covered by the gills. Broadly U-shaped transverse bars extend across the ventral side of the segments. All these spots widen to rearward, segment 9 being mostly brown. The gill plates on segments 3 to 7 extend obliquely toward the mid-dorsum, and are scarcely overlapped except the last pair which is smaller and paler. Around the bases of the legs are some more obscure brownish areas.

Figures of all these Utah nymphs that have not already been figured by Eaton and Dodds will be published shortly in a bulletin from the Utah Agricultural Experiment Station.

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THE EFFECT OF MONOCHROMATIC LIGHT ON FORMICA DAKOTENSIS SPECULARIS (EMERY).

C. E. Abbott.

INTRODUCTION.

Early attempts to study the color-vision of insects often led to erroneous conclusions. The absurd tests made with pieces of colored paper remind us how meager must have been the knowledge of the physics of color possessed by many experimenters in the past. As late as 1912, Seitz (4), in his own field a thoroughly competent entomologist, published a short paper that displayed a profoundly poor knowledge of physical optics.

But Lubbock (2), long ago, made reliable tests on the color-vision of insects. He had no way of equalizing the intensity of different sourses of light, but he overcame the difficulty by varying the absorbtion of his filters and taking averages of these results. The spectral range of his filters was carefully determined. He worked much with ants, and while his results differed somewhat from mine, the species of insects tested also differed in the two cases. Lutz (3) has recently confirmed and extended many of Lubbock's conclusions. We are now beginning to employ more exact methods of research than those of Lubbock. Such methods have been exemplified by the work of Gross (1) on various arthropods. The methods employed in the following experiments have been as exact as limited time and improvised apparatus would permit.

RESULTS.

Under this head only the numerical data are given. Four definitely determined light intensities and four color filters were used. White light was also tried. Five tests for each filter at each intensity were taken as indicated; the averages made from these were accepted as final values.

White light	72. (red)	73. (yellow)	74. (green)	75. (blue-green)
2 cm.	2 cm.	2 cm.	2 cm.	2 cm.
45 minutes	12 minutes	20 minutes	55 minutes	30 minutes
20 "	15 "	10 "	45 "	30 "
25 "	40 "	20 "	11 "	30 "
10 "	22 "	10 "	5 "	15 "
11 "	15 "	8 "	20 "	15 "
22.2 average	28 average	13 average	27.2 average	24 average
3 cm.	3 cm.	3 cm.	3 cm.	3 cm.
16 minutes	8 minutes	10 minutes	19 minutes	15 minutes
11 "	7 "	10 "	14 "	15 "
5 "	10 "	11 "	15 "	15 "
8 "	8 "	5 "	10 "	4 "
5 "	8 "	6 "	12 "	6 "
9 average	8.2 average	8.4 average	14 average	11 average
4 cm.	4 cm.	4 cm.	4 cm.	4 cm.
3.5 minutes	7 minutes	2.5 minutes	3.5 minutes	5 minutes
6 "	11 "	4.5 "	6 "	10 "
7 "	8 "	6 "	7 "	8 "
6 "	16 "	4 "	6 "	4 "
4 "	9 "	7 "	4 "	7 "
5.3 average	10.2 average	4.8 average	5.3 average	6.8 average
5cm.	5 cm.	5 cm.	5 cm.	5 cm.
3 minutes	5 minutes	2.5 minutes	3.5 minutes	4 minutes
4 "	7 "	3 "	7 "	4 "
5 "	6 "	3 "	7 "	6 "
5 "	12 "	4.5 "	10 "	6 "
8 "	10 "	5 "	1 "	7 "
5 average	8 average	3.6 average	7.9 average	5.4 average

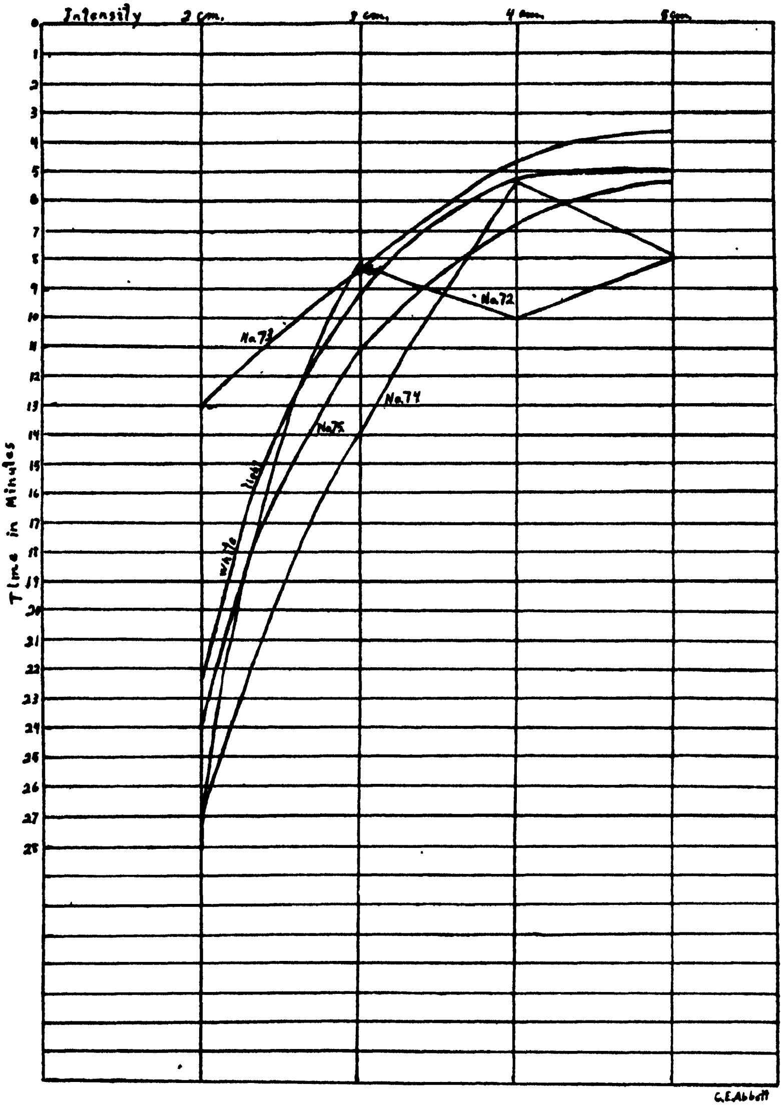
DISCUSSION.

These experiments were performed in August, 1925. Advantage was taken of the fact that *F. dakotensis specularis*, like most ants, carry their exposed pupae from the light into the dark. The insects were kept in a large artificial nest surrounded by a moat filled with oil. The interior of this nest was made of plaster of Paris, and contained several circular depressions about two inches in diameter and about one-fourth inch deep. A glass plate completely covered the nest at the approximate height of one fourth of an inch. The ants kept the pupæ chiefly in the depressions. For each experiment one of those was chosen that had its floor completely covered with a single layer of pupæ. The length of time the ants required to remove the pupæ when light of a given color and intensity fell upon them, was considered inversely proportional to the stimulating value of the light employed.

The colony remained during the whole series of experiments in a room that was perfectly dark excepting at the time that the experimental light was used. The room was so constructed that the temperature, by actual measurement, rarely varied from 23° C. Even when variations in temperature did occur, they were always less than 1° C.

The source of light was a 100 watt incandescent bulb mounted on a wooden block and contained in a wooden box 40 x 8 x 8 inches. The block, as well as the affixed bulb, could be raised or lowered by means of a pulley. A hole two inches in diameter allowed the passage of the rays employed. The entire machine was supported at a constant height over the nest, but could be moved so that the light could be used in any part of the colony. A water-cell one inch thick prevented the transmission of infra-red. A ground-glass plate increased the diffusion. The various layers of glass through which the light passed excluded the ultra violet. The colors were obtained by the use of Wratten filters manufactured by the Eastman Kodak Company. They are catalogued as No. 72 (red), No. 73 (yellow), No. 74 (green), and No. 75 (blue-green). They are probably as nearly monochromatic as any filters that can be obtained.

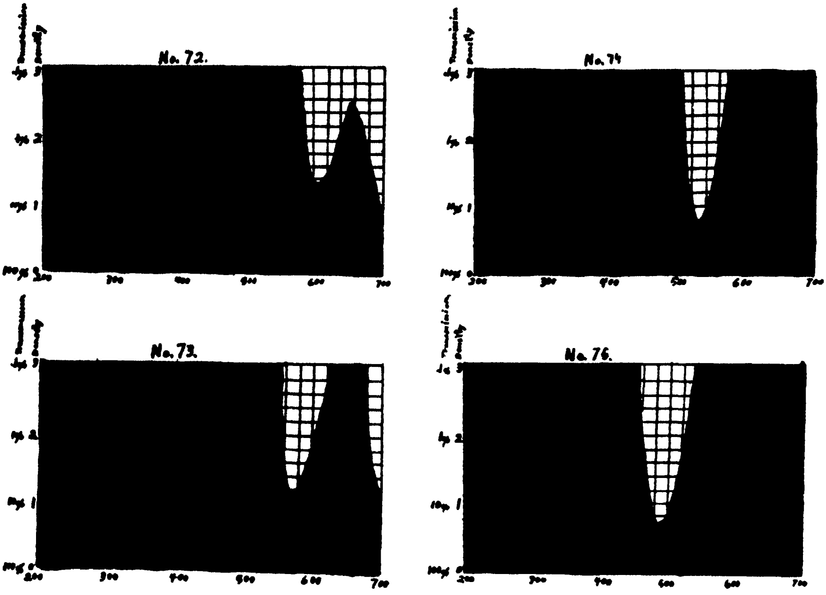
To obtain light of a given intensity a Coblentz thermopile and a Leeds and Northrup galvanometer, connected in series,



TRANSMISSION OF FILTERS.

Horizontal numbers represent spectroscope readings.

were used. The height of the bulb was varied until the desired reading appeared on the galvanometer scale. The position of the block was then marked on the side of the box; next to this mark the galvanometer reading and the filter employed were indicated. All that was needed to obtain the same intensity at another time was to use the appropriate filter and to shift the block until it was flush with this mark. In this way the various intensities for each filter as well as for white light, were controlled.



Reactions of *F. dakotensis specularis* to light.

Graphs giving the percentage of transmission and the color values of the filters accompany this paper. They are copied, with permission, from the bulletin published by the Eastman Kodak Company.

CONCLUSIONS.

The accompanying graph indicates all the results of these researches. The terms used need no explanation. It seems, from the results, that what appears to the human eye as yellow has the greatest stimulating value of any of the colors used for *F. dakotensis specularis.* White light is second only to yellow. Lubbock's ants were most sensitive to green. It is also evident that the stimulating value of light at different intensities, irrespective of its color, is a more or less characteristic curve approaching a constant value. The irregular results with the green and red filters may possibly be explained by insufficient data; otherwise they remain a mystery. The ants reacted to white light exactly as they did to the colors. Their reaction to red may be explained by the fact that filter No.72 transmitted some yellow. It is improbable that the insects would react to pure red.

In closing, I wish especially to thank Mr. Hampton of the Botany Department of the University of Wisconsin for the use of apparatus and for various information. Thanks are also due Dr. W. M. Mann of the Bureau of Entomology for the identification of specimens, and to the Eastman Kodak Company for permission to reproduce graphs. I also am obliged to Dr. L. E. Noland for various favors.

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NORTH AMERICAN SPECIES OF POLYMEDON. (DIPTERA DOLICHOPODIDÆ).

M. C. Van Duzee,
Buffalo, N. Y.

The genus *Polymedon* was described by Osten Sacken in Western Diptera; Bull. of the United States Geological Survey of the Territories, iii, 317, 1877. Up to the present time all the species described have come from America. Dr. Becker described *longifacies* from South America and Dr. Aldrich described *superbus* from St. Vincent, W. I. The remaining eight forms are all from North America.

The genus is very nearly related to *Tachytrechus*, differing from that genus in having the face greatly elongated, especially in the male, extending considerably, somtimes very greatly, below the lower corners of the eyes; the lower part forming a thin plate or ribbon, which hangs down over the proboscis.

The habits of these flies are about like those of the *Tachytrechus*, they are found on stones in streams or about water falls. Four species have been found in the deep canons of Arizona, three of them in the Grand Canon.

Table of Males.

1. Femora black..2
   Femora yellow..3
2. Antennæ reddish on underside.......................**flabellifer** O. S.
   Antennæ wholly black.......................................**angustatus** Ald.
3. Costa greatly enlarged before the tip of first vein.........................4
   Costa scarcely enlarged..5
4. Hypopygial lamellæ with two projections, one short, the other long and with a few long pale hairs at tip...............................**nimius** Ald.
   Lamellæ with three projections, the short blunt one on one side, a little longer one on the other side, with a sharp point at tip, and a still longer one in the center, which has a few long pale hairs at tip and many flattened, blunt ones towards the base..................................**dilaticosta** new species
5. Hypopygial lamellæ small, triangular...................**triangularis** Ald.
   Hypopygial lamellæ larger, quadrangular...................**superbus** Ald.

Table of Females.

1. Femora black..2
   Femora largely yellow, or wholly yellow....................................4
2. Tibiæ black.......................................**flabellifer** O. S.
   Tibiæ yellow..3
3. Antennæ wholly black?.......................................**argentatus** Ald.
   Antennæ yellow below...........................**nigrifemoratus** new species

4. Middle and hind femora with a blackish stripe on lower surface, **castor** Wheeler
   Femora wholly yellow, or a little darkened above at tip..................5
5. First and second antennal joints wholly yellow............................6
   First and second antennal joints narrowly black above.....................7
6. Middle and hind coxæ yellow with a blackish streak on outer surface. Length, 3.5 mm...**nitidus** new species
   Middle and hind coxæ black except at tip and on inner side. Length, 5 mm., **triangularis** Ald.
7. Face reaching nearly its width below the eyes.............**castor** Wheeler
   Face reaching but little below the eyes..8
8. Face rounded below.....................................**dilaticosta** new sp.
   Face ending in a point below...9
9. General color of thorax and abdomen deep blue, verging into green, **superbus** Aldrich
   General color of thorax and abdomen green, not at all blue...**nimius** Aldrich.

Polymedon dilaticosta new species.

Male: Length 5 mm.; of wing, 6 mm. Face and front silvery white, the former extending nearly twice its width below the eyes. Antennæ with the first joint long, first and second joints yellow, narrowly black on upper edge; third joint short, oval, brown with a yellow spot below; arista thick, as long as the antenna. Orbital cilia yellowish white, about eight of the upper ones on each side black.

Dorsum of thorax and abdomen shining green, sides of the former and spots on the sides of the segments of the latter with silvery white pollen; hairs of the abdomen black. Hypopygium pedunculate, black, yellowish below; lamellæ rather large, brown, paler at base, they have a slender stem and three angles, a short, blunt angle below, one a little longer above that has a sharp point at tip; a still larger one in the center, they have several long, delicate, pale hairs near the tip and many rather long, flattened, blunt ones on basal portion. One black propleural bristle above fore coxæ.

Fore coxæ yellow, with silvery white pollen, a few minute pale hairs and several black bristles at tip. Middle and hind coxæ black with yellow tips. Femora and tibiæ yellow; posterior pair of both a little brown at tip. Hind tibiæ with about seven large bristles above, a row of small ones on upper posterior edge of apical half and a row of very small ones on lower surface which are not much more than hairs with three larger ones in the row. Middle and hind tarsi black from the tip of first joint, posterior pair black almost to their base, their first joint with a small bristle below near the base; fore and middle tarsi both with a row of bristle-like hairs below. The bend between second and third joints of middle tarsi found in the male of several species is conspicuous in this form. Joints of fore tarsi as 51–17–14–12–13; of middle ones as 71–32–23–16–13; of posterior pair as 52–61–36–21–16. Calypters and halteres yellow, the former with very long, dense, black cilia, the hairs being as long as the face. Wings tinged with brown; costa filling in most of the space to first vein, this thickening ending before the tip of the first vein; anal angle very prominent.

Female: Face reaching a little below the lower edge of the eyes, rounded below. Antennæ, thorax, legs and feet about as in the male, except that the middle tarsi are plain and the length of the tarsal joints vary somewhat. Cilia of the calypters long, but not unusually so, black. Wings with a very slight bordering of brown on the veins; costa a very little thickened before the tip of first vein.

Described from nine males and three females, taken on the Bright Angel Trail, Grand Canon, Arizona, and one female taken in Oak Creek Canon, Arizona, August, at an elevation of 6,000 feet; the last one was taken by F. H. Snow.

Type and allotype in the Canadian National Collection.

Polymedon nitidus new species.

Female: Length, 3.5 mm.; of wing the same. Face and front covered with silvery white pollen, the former extending about half its width below the eyes, rounded on lower margin. Palpi black, covered with white pollen and black hairs; proboscis with pale hairs. Antennæ yellow, third joint brown at tip, nearly round, but obtusely pointed at tip. Lateral and inferior orbital cilia white, a few of the upper ones black.

Thorax and abdomen green, shining, the latter with black hairs, the former on anterior half with gray pollen and black hairs.

Coxæ yellow. Middle and hind coxæ infuscated on outer surface of basal half; anterior pair with little black hairs on the front side and a row of about eight black bristles at tip. Femora and tibiæ wholly pale yellow; posterior pair with a bristle at apical third and minute pale hairs below; middle tibiæ with a bristle just beyond apical third on lower anterior edge; middle and hind tibiæ with large bristles above, the latter without bristles below, but with a row of rather long, black hairs below. Tarsi black from the tip of the first joint; fore and middle basitarsi with little spines below, the posterior ones with a rather long bristle near the base below. Joints of fore tarsi as 37–12–10–7–10; of middle pair as 42–25–15–13–9; those of posterior pair as 34–40–25–14–13. Calypters and halteres yellow, the former with black cilia.

Wings grayish; costa thick as before the tip of first vein as beyond; last section of fourth vein bent quite abruptly the length of the cross-vein beyond that vein, a little arched beyond the bend; anal angle prominent.

Described from one female, taken on the Bright Angel Trail, Grand Canon, Arizona.

Type in the Canadian National Collection.

Polymedon nigrifemoratus new species

Female: Length, 5 mm.; of wing the same. Face and front black with white pollen, the ground color showing through on the front, face extending a little below the eyes. Palpi small, brown with pale hairs. Antennæ black, first joint on lower half of apical half, second on inner side below and a spot on third below, yellow; third joint nearly round; arista black at base, yellowish beyond its first joint. Lateral and inferior orbital cilia whitish, about five of the upper cilia on each side black.

Dorsum of thorax brown with green reflections, its pollen gray, more brown on central portion; pleuræ more black with white pollen. Abdomen green, covered with white pollen and black hair; propleuræ with a few pale hairs and one large black bristle above fore coxæ.

Coxæ and femora black with yellow tips and white pollen; fore coxæ with minute black hairs on anterior surface and eight bristles at tip. Middle femora with a small preapical bristle on each side; posterior pair with four large bristles on upper anterior edge, ending in the preapical bristle. Tibiæ yellow with their tips a little brown, all with large bristles above; fore tibiæ with a large bristle on lower posterior edge near the middle; middle ones with two large bristles below, one near the middle and one at apical fourth; posterior pair with a row of six hair-like bristles on lower surface. All tarsi infuscated from the tip of the first joint, but base of second joint more or less yellow; all joints with small bristles at tip, posterior basitarsus with a large bristle near the base below; anterior basitarsi with small spines below. Joints of fore tarsi as 42–13–11–9–13; of middle ones as 65–30–24–12–13; those of posterior pair as 51–50–38–19–16. Calypters and halteres yellow, the former with black cilia which appears reddish in certain lights.

Wings grayish; cross vein bordered with brown; first section of costa very slightly thickened; last section of fourth vein bent a little before its middle, considerably arched beyond this bend; anal angle prominent.

Described from one female, taken in Oak Creek Canon, Arizona, at an elevation of 6,000 feet, in August.

Type in the author's collection.

This was probably taken by F. H. Snow although his name is not on the label.

Polymedon castor Wheeler.

Females that Dr. Aldrich and I have determined as this species have one large black spine at tip of palpi, there is a blackish stripe densely covered with white pollen on lower posterior edge of all femora; the posterior femora have two large preapical bristles; middle tibiæ with three, posterior ones with four large bristles below; posterior basitarsi wholly black with a large bristle near the base below.

ANOTHER INSECT VECTOR OF THE GIANT THORN-HEADED WORM OF SWINE*

Xyloryctes satyrus Fabricius (Scarabaeidae)

Both Genus and Species New to the Host List of this Parasite.

By ROBERT D. GLASGOW.

It has been shown that certain meadow-inhabiting species of North American May beetles† may serve as intermediary hosts to the giant thorn-headed worm of swine, *Macracanthorhyncus hirudinaceus* (Pallas) Travassos. The eggs of this worm occur in the "droppings" of infested swine; and from the excreta of these animals are washed into the soil by rain. The eggs may then be swallowed by grubs of the beetles indicated, while feeding on the roots of grasses or of other plants. In the body of the grub the parasite passes through the so-called larval stage of its life cycle; and when this "larval" development is completed, the worm becomes encysted within the tissues of the insect host. The cysts of this parasite may remain quiescent within the body of the infested grub for considerable periods of time; and they may even persist through the transformation of the insect host, and probably may be transported from one field to another by the flight of the infested adult beetle. The worm finally reaches its definitive host and completes its development when a pig happens to eat a grub or a beetle that harbors the encysted parasite.

Therefore, land inhabited by grubs or visited by adults of the May beetle species cited above, affords a suitable habitat for the transmission of this parasite from pig to pig. In addition to lands harboring these primarily meadow-inhabiting intermediary host species, the forest also must now be recognized as a particularly favorable habitat for the dissemination of the giant thorn-headed worm, since the writer has just recently found *Xyloryctes satyrus* Fabricius to be a suitable host for its "larval" development.

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*Contribution from the Entomological Laboratories of the University of Illinois, Number 107.

The studies upon which this report is based were begun at the University of Illinois, and continued during the summer of 1926 at the New York State Agricultural Experiment Station at Geneva, New York. The writer is indebted to the officers of that institution, and particularly to Professor P. J. Parrott and Dr. Hugh Glasgow for the facilities provided which made the continuance of the work practicable at that time.

†*Phyllophaga* spp. (species undetermined, but thought by Dr. L. O. Howard most probably to be *P. fervida* Fabricius (*arcuata* Smith), Stiles, C. W., Bull. de la Soc. Zool. de France, vol. 16, pp. 240-242, 1891. *Phyllophaga rugosa* Melsheimer, Glasgow, R. D., Ann. Ent. Soc. of America, vol. 19, pp. 252-254, 1926.

Not only may the larva of *Xyloryctes satyrus* harbor the cysts of the giant thorn-headed worm, but the cysts, established in larvæ fed upon material contaminated with eggs of the parasite, have been carried by the writer through the transformation of this insect host, and recovered from the adult beetle.

The accompanying figures show some of the cysts of the giant thorn-headed worm in a larva, and in an adult beetle of *Xyloryctes satyrus* from which portions of the body wall have been cut away. In another instance, four hundred and ten cysts were counted in a single *Xyloryctes* larva.

Xyloryctes satyrus is a forest inhabiting species; the larvæ are large, and they seem to possess a considerable degree of tolerance for rather heavy infestations of the giant thorn-headed worm; they are usually abundant wherever they occur; and their habits would seem to expose them both to contamination by eggs of the parasite, and to capture by foraging pigs. *Xyloryctes satyrus* appears therefore to be a particularly dangerous potential factor in the dissemination of this important intestinal parasite, among swine that may be pastured upon or have access to forest covered land.

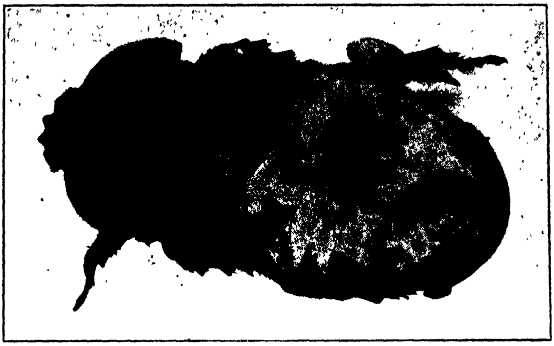

FIG. 1. Cysts of *M. hirudinaceus* in adults of *Xylorycles satyrus*. Eleven cysts were taken from this particular beetle.

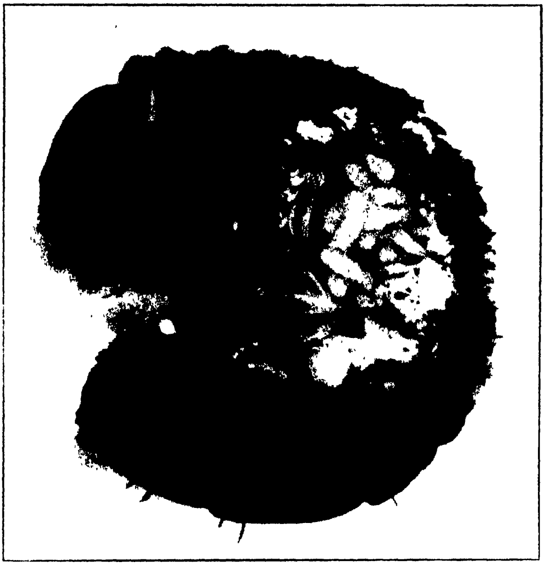

Fig. 2. Cysts of *M. hirudinaceus* in larva of *Xylorycles satyrus*. Four hundred and ten cysts were counted in a single larva of this species.

R. D. Glasgow.

PROCEEDINGS OF THE TWENTY-FIRST ANNUAL MEETING

PHILADELPHIA, PENNSLYVANIA, DECEMBER 27 AND 28, 1926.

The Twenty-first Annual Meeting of the Entomological Society of America was characterized by an unusually large attendance and interest. The attendance at the sessions ranged from 65 to 250, the average attendance for the five sessions being 133.

An outstanding feature of the meetings was a scholarly address on the subject, "Insect Parasites of Man", delivered at the evening public meeting by Prof. George H. F. Nuttall, of Cambridge, England. Another interesting part of the program was the symposium on "Needed Lines of Investigations in American Entomology." A number of interesting exhibits were prepared by members.

OPENING SESSION, TUESDAY MORNING, DECEMBER 27.

The Society was called to order at 10:00 A. M. by President William A. Riley, in Room 110, Logan Hall, University of Pennslyvania. Attendance 110. The following papers were presented; those starred by title only.

*1. Three New Species of Phytomyza (Agromyzidæ, Diptera). S. W. FROST, Arendtsville, Pa.
*2. A New Rabbit Brush Aphid from Utah. GEORGE F. KNOWLTON, Utah Agricultural Experiment Station.
3. The Variability of *Aphis gossypii*. C. H. BATCHELDER, University of Maine.
4. The Hippoboscid Fly, *Ornithomyia avicularia* Linn., as a Carrier of Mallophaga. H. E. EWING, U. S. National Museum.
*5. Embryonic Development in the Lepidoptera. O. A. JOHANNSEN, Cornell University.
6. The Development of the Castes of Bumblebees (Bremidæ, Hymenoptera). THEODORE H. FRISON, University of Illinois.
7. The Making of Microscopical Whole-Mounts of Insects. J. D. HOOD, University of Rochester.
8. Potentiometer Measurements of the Blood of Insects. DAVID E. FINK, U. S. Bureau of Entomology.
9. Remarks on the Distribution of Aquatic Hemiptera. H. B. HUNGERFORD, University of Kansas.
10. A Bibliography of Biographies of Entomologists. JOE S. WADE, U. S. Bureau of Entomology.
*11. The Biology and Immature Stages of the Sandflies (biting Ceratopogoninæ) at Puerto Castilla, Honduras. REGINALD H. PAINTER, Ohio State University.

The following Committees were appointed by the President:

Nominating Committee—J. S. HOUSER, (Chairman) E. O. ESSIG, P. W. CLAASSEN.
Resolutions Committee—H. B. HUNGERFORD, (Chairman) T. L. GUYTON, Z. P. METCALF.
Auditing Committee—J. M. ALDRICH, (Chairman) T. H. FRISON, D. M. DELONG.
International Congress Committee—P. P. CALVERT, (Chairman), E. D. BALL, F. E. LUTZ.

SECOND SESSION, TUESDAY AFTERNOON, DECEMBER 27.

The Society was called to order at 1:45 P. M. in Room 110, Logan Hall, University of Pennslyvania, by President Riley. Attendance 165. The following Symposium was presented:

"Needed Lines of Investigation in American Entomology"
Introduction, E. D. Ball.
1. In Taxonomy, S. A. ROHWER.
2. In Morphology, E. M. WALKER.
3. In Physiology, P. S. WELCH.
4. In Bionomics, R. W. DOANE.
5. In Ecology, W. C. ALLEE.
6. In Distribution, C. H. KENNEDY.
7. In Economic Entomology:
   (a) Needs in Study of Beneficial Insects, L. O. HOWARD.
   (b) Needs in Study of Insect Injuries, E. O. ESSIG.
   (c) Needs in Study of Control Measures, W. P. FLINT.

Summary, E. F. PHILLIPS.

THIRD SESSION, TUESDAY EVENING, DECEMBER 27.

The Society was called to order at 8:00 P. M. in the Lecture Hall, Philadelphia Academy of Science, by President Riley. Attendance 250.

The annual public address given at this session was made by Prof. George H. F. Nuttall, Cambridge, England, on the subject "Insect Parasites of Man."

The address was followed by a smoker in the Academy Building, tendered to all visiting entomologists by the local entomologists of Philadelphia.

FOURTH SESSION, WEDNESDAY MORNING, DECEMBER 28.

The Society was called to order at 10:15 A. M. in Room 110, Logan Hall, University of Pennslyvania, by President Riley. Attendance 75. The following papers were presented:

12. Do the Eupteryginæ Show Venation in the Basal Portion of the Elytra? D. M. DELONG, Ohio State University.
13. The Axillary Region of the Wing. WILLIAM T. M. FORBES, Cornell University.
14. Notes on the Biology and Habits of the Peruvian Cotton Square Weevil. W. E. HINDS, Louisiana State University.
15. A Method of Computing Mean Temperature for Biological Use. C. R. CUTRIGHT, Ohio Agricultural Experiment Station.
16. An Ecological Study of an Inland Salt Water Stream. P. W. CLAASSEN, Cornell University.
17. Insects of the Upper Air. E. P. FELT, New York State Museum.
18. Collecting Diptera in Guatemala. J. M. ALDRICH, U. S. National Museum.
19. Cold Hardiness in the Second and Third Instar of the Japanese Beetle (*Popillia japonica*). NELLIE M. PAYNE, University of Pennslyvania.
20. Orientation Reactions of Certain Whirligig Beetles. CARL R. BROWN and MELVILLE H. HATCH.

FIFTH SESSION, WEDNESDAY AFTERNOON, DECEMBER 28.

The Society was called to order a 1:45 P. M. by Vice-president Braun in Room 110, Logan Hall, University of Pennslyvania. Attendance 65. The following program was presented:

21. Factors in Phylogenetic Development. A. W. LINDSEY, Denison University.
22. The Olfactory Sense of Coleoptera. C. E. ABBOTT, Johns Hopkins University
23. A Preliminary Report on the Reponse of the Oriental Peach Moth and Codling Moth to Colored Lights. ALVAH PETERSON and G. J. HAEUSSLER, U. S. Bureau of Entomology.
24. The Ways of Wasps. H. T. Fernald, Massachusetts Agricultural College.
25. System in Scientific Names. E. P. FELT, New York State Museum.
26. A New Record Relative to the Parasites of *Pholus achemon* Drury. HAZEL E. BRANCH, University of Wichita.

The following excellent exhibits were on display in Room 212, Logan Hall, University of Pennslyvania, during the sessions:

1. *Diatraea saccharalis*—Sugar Cane Borer—Stages of Life History and Specimens of Work, by W. E. HINDS, Louisiana Agricultural Experiment Station.
2. *Anthonomus vestitus*—Peruvian Cotton Square Weevil, by W. E. HINDS, Louisiana Agricultural Experiment Station.
3. Specimens of Thysanoptera, showing Technique as Discussed in Paper on Program, by J. D. HOOD, University of Rochester.
4. An Electro-Gutzeil Apparatus for the Quantitative Estimation of Minute Amounts of Arsenic in Insects, by DAVID E. FINK, U. S. Bureau of Entomology.
5. Mounted Elytra of Eupteryginæ (Homoptera, Cicadellidæ), to show Venation, by D. M. DELONG, Ohio State University.
6. Japanese Beetle Exhibit, by LOREN B. SMITH, U. S. Bureau of Entomology.
7. Illustrations of Certain Phases of the Nomenclatural Situation, by E. P. FELT, New York State Museum.

The completion of the reading of papers was followed by the annual business meeting.

REPORT OF THE SECRETARY.

On March 24, 1926, the following, having been duly nominated and recommended, were elected members of the Society by mail ballot of the Executive Committee:

DWIGHT E. MINNICH, University of Minnesota, Minneapolis, Minn.
ROBERT W. DEVESON, Rochester, N. Y.
MARGARET HAIGH, Dearborn, Mich.
W. J. BROWN, Oklahoma Agricultural College, Stillwater, Oklahoma.
M. Y. MARSHALL, Mosley Hospital, Henderson, Ky.
ERNEST MORTENSEN, UVALDE, Tex.
C. O. DIRKS, Purdue University, Lafayette, Ind.
FRITZ CARPENTIER, Institute Ed. Van Beneden, Liege, Belgium.

By direction of the Executive Committee, Prof. Geo. H. F. Nuttall was invited to give the annual public address of the Society at the Philadelphia meeting. By mutual consent it was decided to hold a symposium on the subject, "Needed Lines of Investigation in American Entomology."

Dr. P. P. Calvert kindly consented to act as local representative for the Philadelphia meeting.

The Excutive Committee met at 5:00 P. M. December 28, 1926, in Logan Hall, University of Pennslyvania, with the following members present: W. A. Riley, Edith M. Patch, Annette F. Braun, J. A. G. Rehn, J. M. Swaine, Herbert Osborn, F. E. Lutz, and J. J. Davis.

The following members were elected:

Horace Francis Barnes, S. E. Agricultural College, Wye, Ashford, Kent, England.
Ralph D. Bird, 203 Vivarium Bldg., Univ. Ill., Champaign, Ill.
E. P. Breakley, 1539 Vermont St., Lawrence, Kansas.
W. H. Brittain, Macdonald College, P. O., Quebec, Canada.
Oscar L. Cartwright, Oswego, South Carolina.
Floyd L. Clarke, Newton, Utah.
Cecil N. Davis, 108 Whitten Hall, Columbia, Mo.
Lorin Fife, 345 N. Third East, Logan, Utah.
Paul B. Fuller, 1717 Third Ave., Evansville, Ind.
George Hendrickson, Dept. Entomology, Iowa St. College, Ames, Iowa.
H. G. Johnston, Dept. Zoology, Iowa Agric. College, Ames, Iowa.
Mohammed Kamal, Div. Ent., Ministry of Agriculture, Cairo, Egypt.
Stephen C. Kleene, Amherst College, N. H.
Wm. F. Lawler, Jr., 38 Murray St., New York, N. Y.
Frank H. Letl, Sublette, Ill.
S. F. Light, Dept. Zoology, Univ. California, Berkeley, Calif.
Paul Robert Needham, Roberts Hall, Cornell Univ., Ithaca, N. Y.
U. S. L. Pate, 5703 N. 6th St., Philadelphia, Pa.
S. F. Potts, 17 E. Highland Ave., Melrose Highlands, Mass.
Wm. Robinson, Dept. Entomology, University Farm, St. Paul, Minn.
Herbert H. Schwardt, Dept. Entomology, Kans. St. Agri. Col., Manhattan, Kans.
Herbert Ferlando Schwarz, Amer. Mus. Nat. His., 77th St. and Central Park West, New York, N. Y.
Charles J. Sorenson, Agric. Expt. Sta., Logan, Utah.
Frank E. Todd, Bureau Plant Quarantine, Dept. Agric., Sacramento, Calif.
Lawrence Albert Zimmer, 97 W. 9th Ave., Columbus, Ohio.

The following members have died during the year 1926:

E. T. Cresson, Sr.
E. A. Hartley
Chas. W. Minott*
Henry Skinner
Annie T. Slosson

The following persons resigned during the year and their memberships terminated December 28, 1926:

C. I. Bliss
F. W. Boyd
E. K. Bynum
E. R. Downing
J. Evenden
J. E. Guberlet
R. H. Howe, Jr.
R. L. King
C. W. Leng
M. E. Mosely
F. B. Paddock
G. E. Sanders
Wm. Schaus
R. H. Van Zwaluwenburg
G. P. Weldon
A. B. Wells
V. J. Zabrobsky

A number of those resigned report that they requested their resignation a year ago which may account for the large number of resignations this year.

Total membership December 30, 1925 (See Annals XIX, p. 106)		689
Members lost by death	5	
Members lost by resignation	17	
Loss in membership during 1926		22
Balance		667
New members elected during 1925		33
Total present membership		700

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*Died Nov. 28, 1925.

The following members were recommended for fellows in the Society: W. S. Blatchley, E. O. Essig and W. R. Thompson.

The following were elected members of the Thomas Say Foundation: E. C. Van Dyke and Nathan Banks, to succeed themselves.

The following were elected members of the Editorial Board of the Annals: J. A. G. Rehn, H. E. Ewing and R. W. Doane to succeed Wm. Schaus, E. C. Van Dyke, and W. E. Britton.

It was decided that no change be made in the investment of the permanent funds.

Respectively Submitted,

J. J. DAVIS, *Secretary.*

On motion, the Secretary's Report was accepted. The next item of business was the

REPORT OF THE TREASURER.

CURRENT FUNDS

RECEIPTS.

Balance, Dec. 30, 1925 (See Annals XIX, p. 107)	$1,912.55
From Annual Dues of Members	2,092.95
From Managing Editor of the Annals	975.75
From interest on bonds	47.42
From interest on deposit, April 1-July 1	20.00
Total	$5,048.67

EXPENDITURES

Express charges	5.56
Telegrams	.48
Refund on checks returned	12.00
Printing of 1925 programs	38.70
To H. Osborn for copies of Annals	2.00
Stamped envelopes	21.92
Stamps	42 11
Stenographic services, 1925	15.00
Stenographic services, 1926	66.90
Rubber Stamp	84
Letter heads and notice cards	22.00
Lettering certificates	10.10
Envelopes for preliminary notices	3.50
Printing preliminary notices	10.00
Printing 1925 Annals	1,749.43
Total	$2,000.54
Balance, Cash on Hand, Purdue State Bank, Dec. 15	3,048.13
	$5,048.67

LIABILITIES.

The Society owes the publishers of the Annals for the March, June, September and December issues of the current year. We also owe $32.00 for printing of the programs and about $5.00 for clerical help.

PERMANENT FUND

The Society holds United States and Canadian Liberty Bonds totaling $1,100. as listed in the Annals, vol. XIX p. 108.

Respectively submitted,

J. J. DAVIS, *Treasurer.*

On motion the Treasurer's Report was accepted, subject to the approval of the Auditing Committee.

The report of the Auditing Committee was next called for:

The undersigned auditing committee have examined the books of Herbert Osborn, editor of the ANNALS, and of J. J. Davis, Secretary-Treasurer of the Society and Treasurer of the Thomas Say Foundation, and find the same to be correctly kept and balances on hand as reported by them.

(Signed) J. M. ALDRICH, *Chairman*,
T. H. FRISON,
D. M. DELONG.

President Riley then asked for the report of the Managing Editor of the Annals by Professor Osborn.

REPORT OF THE MANAGING EDITOR.

During the past year we have made progress in securing additional subscriptions and note with interest that the numbers going to foreign countries have been increased. The Annals now go to every state in the Union except one, Vermont, and to District of Columbia, Hawaii, Porto Rico and the Philippines.

The contents of the year have covered a wide range of entomological subjects and include a number of papers of broad biologic interest.

As in previous years, a number of authors have contributed toward the preparation of illustrations and in some cases, to part cost of the printing and we may note particularly, contributions from the Rockefeller Foundation for Medical Research and the Tropical Plant Research Foundation to provide for publication of articles and to the Colorado Experiment Station for the provision of colored plates, illustrating one of the articles.

A number of articles are in hand and we are assured of a good supply of material for the coming year.

I wish to thank the members of the Editorial Board for the support during the year and particularly to express obligation to Dr. C. H. Kennedy for his continued help in the management of the Journal.

The receipts and expenditures have amounted to $1299.20 and are summarized in the following statement:

RECEIPTS.

Non-member subscriptions (continuations)	$ 346.37
Non-member subscriptions (new)	48.80
From sale of back volumes and numbers	457.85
From payments on extra reprints	155.57
From payments on engravings	290.61
Total	$1,299.20

DISBURSEMENTS.

Postage and mailing account	$ 66.09
Engraving bills paid	219.84
Stenographic and clerical help	34.00
Miscellaneous expense	3.52
Balance remittances to Treasurer	975.75
Total	$1,299.20

HERBERT OSBORN, *Managing Editor.*

The report of the Treasurer of the Thomas Say Foundation was then called for.

REPORT OF THE TREASURER OF THE THOMAS SAY FOUNDATION

For the Year 1926.

RECEIPTS

Balance on hand January 1, 1926	$ 65.02
Payments on Vol. 1, delivered previous to Jan. 1:	
2 @ $3.00 and 1 @ $2.55	8.55
Sale of vol 1:	
3 @ $3.00	9.00
3 @ $2.25	6.75
1 @ $3.14	3.14
Payments on vol. 2, delivered previous to Jan. 1:	
12 @ $5.00 and 1 @ $4.67	64.67
Sale of volume 2:	
8 @ $5.00	40.00
6 @ $4.50	27.00
1 @ $4.95	4.95
Loan to pay printing bill for volume 2	565.00
	$794.05

EXPENDITURES

Postage on volumes mailed	$ 5.74
Postage stamps	3.00
Interest on $150 @ 6% Oct. 1, 1925—Jan. 1, 1926	2.25
Interest on loan $565.00 Jan. 1, to July 1, 1926	16.95
Lafayette Printing Co., Balance due on vol. 2	652.23
Cash to reduce loan	65.00
Balance on hand	48.88
	$794.05

There is a balance due on loan to pay for printing volume 2 of $500.00

Respectfully Submitted,

J. J. Davis, *Treasurer.*

This report was accepted.

The Editor of the Thomas Say Foundation was called upon for a report. No publications were issued during the year and no report was therefore submitted by Editor Aldrich.

The President next called for the report of the Committee on Resolutions, which was as follows:

Your committee begs to present the following resolutions:

That the Entomological Society of America expresses its appreciation for the facilities placed at its disposal by the University of Pennslyvania through the personal efforts of Dr. P. P. Calvert.

That thanks be extended to the Philadelphia Academy of Natural Sciences and the Entomologists of Philadelphia and vicinity for their splendid hospitality.

That we acknowledge our gratitude to Dr. George H. F. Nuttall of the University of Cambridge for his excellent and instructive address given at the annual public meeting.

That the Society commends its officers for their efforts in providing a program of such general interest. We wish to call especial attention to the instructive character of the exhibits and to recommend that more emphasis be placed upon the display feature.

That the Entomological Society of America deeply regrets the illness of its first president, Prof. J. H. Comstock, who has done so much for this Society and to whose untiring efforts American Entomology owes a great debt of gratitude. That the Society expresses the sincere hope that he may soon recover.

Your committee suggests that the Secretary be instructed to send a copy of these resolutions to Professor and Mrs. Comstock.

Respectfully submitted,
(signed) H. B. HUNGERFORD, *Chairman.*
T. L. GUYTON,
Z. P. METCALF.

The Nominating Committee reported as follows:

The Nominating Committee presents for the approval of the Society the names of the following members:

For President—F. E. LUTZ
For First Vice-President—W. E. HINDS
For Second Vice-President—E. P. VAN DUZEE
For Secretary-Treasurer—J. J. DAVIS
For Additional Members of the Executive Committee—
For Term Expiring Dec. 31, 1929—W. A. RILEY and EDITH M. PATCH.
For Councillors to the American Association for the Advancement of Science—J. M. ALDRICH and C. L. METCALF.
For Committee on National Museum—HERBERT OSBORN, Chairman; C. W. JOHNSON, JAMES G. NEEDHAM, NATHAN BANKS, E. C. VAN DYKE.

Respectfully submitted,
(Signed) J. S. HOUSER, *Chairman,*
E. O. ESSIG,
P. W. CLAASSEN.

By vote of the Society the report was accepted and the Secretary instructed to cast the unanimous ballot of the Society for the election of the persons nominated. This being done they were declared elected.

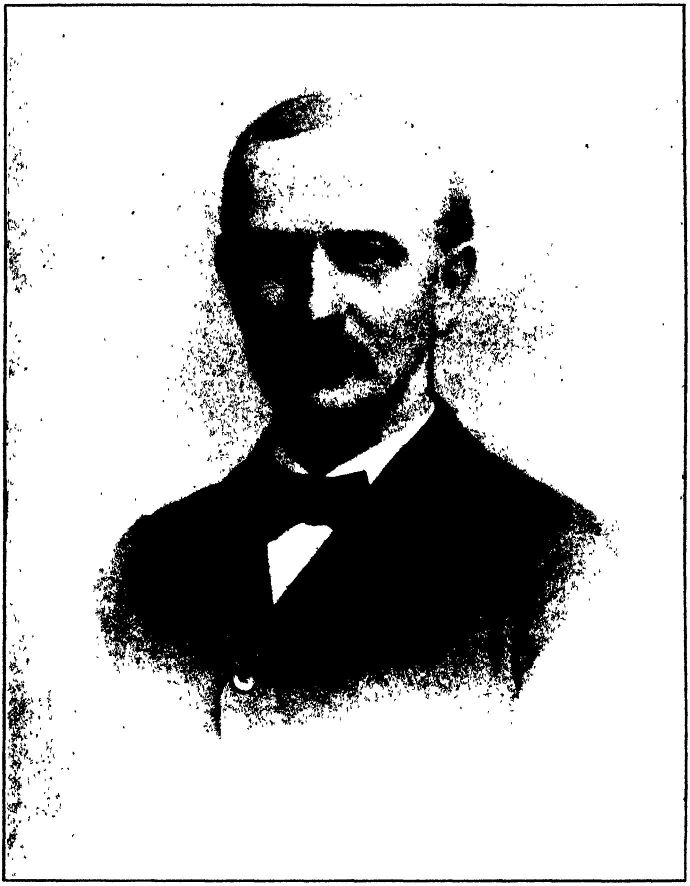
President Riley next called for the report of the committee appointed to consider improvement of our program.

The report follows:

Your committee, appointed to study possibilities for the improvement of programs, working in cooperation with a similar committee of the American Association of Economic Entomologists begs leave to report as follows:

1. It is recommended that the program arrangements be left to the secretaries of the two societies as heretofore.
2. That the annual entomologist's dinner be scheduled as nearly as possible about the middle of the week for the convenience of those who may not wish to remain throughout the economic sessions.
3. It is suggested that consideration be given to holding the meeting at occassional intervals at some entomological center rather than at the scheduled meeting place of the American Association for the Advancement of Science. That this matter be left to the Executive Committees of the two Societies for further consideration and report.
4. It is further suggested that individuals or groups of individuals be requested to consult with the secretaries of the two societies before arranging for special interest meetings.

Respectfully submitted,
(Signed) J. J. DAVIS, *Chairman,*
J. M. ALDRICH,
HERBERT OSBORN.



EZRA TOWNSEND CRESSON (1895)

The special committee on the International Congress then reported as follows:

The Committee on the International Congress of Entomology recommends that the Entomological Society of America, in conjunction with the American Association of Economic Entomologists, invite the Permanent Committee of the Congresses to hold the Fourth International Congress at Ithaca, New York, between August 15 and September 15, 1928. This recommendation does not commit the Society to any expenditures on account of the Congress.

It is suggested that the Committee be continued, to act in conjunction with a corresponding committee of the American Association of Economic Entomologists to make necessary arrangements for the Congress.

Respectfully submitted,

(Signed) P. P. CALVERT, *Chairman*,
F. E. LUTZ,
E. D. BALL.

The special Committee, consisting of P. P. Calvert, Chairman, J. C. Bradley and R. C. Williams, Jr. reported as follows:

RESOLUTIONS ON THE DEATH OF E. T. CRESSON

In the death of Ezra Townsend Cresson, on April 19th, 1926, the Entomological Society of America has suffered the loss of a beloved Honorary Fellow. To those of us who knew him, his memory like an attending presence, will ever remain an inspiration toward the highest goals.

So modest and unassuming was the character of Mr. Cresson, that few of the present generation of entomologists knew him personally, and yet his name is known and honored in whatever part of the world entomology is studied.

We recognize the clear vision that perceived at the outset of his career the imperative necessity for an appropriate vehicle open to all American entomologists for the publication of their researches, and which led him to overcome every obstacle, even to setting the type for the early volumes with his own hands, to the establishment of an entomological serial, the first in the new world, which has not since been rivalled in scholarliness and importance, and which at once assumed and has since maintained a front rank among the learned publications of the world. For forty-two years he actively edited this series.

Not content, he appreciated the need for another serial of different function and was chairman of the committee that in 1889 determined upon the publication of the Entomological News.

At a time when economic entomology was scarcely existant, he edited the Practical Entomologist "for gratuitous distribution among farmers and agriculturalists."

Despite these unceasing labors on behalf of his fellow entomologists, gaining his living all the while as Secretary of an Insurance company, so great was his devotion to science, that he nevertheless produced a long series of monographs on the Hymenoptera, of great merit and distinction, that form for more than a foundation upon which all further studies of the North American Hymenoptera must be built. These labors gained him rank as one of the world's great entomologists of the 19th Century.

The Entomological Society of America can lay no higher tribute than to attest, by rising and unanimous vote, that he lived and accomplished, as they each and severally would live and accomplish, were they gifted with his powers, and were it given to them to realize their ideals.

(Signed) J. C. BRADLEY,
R. C. WILLIAMS, JR.
P. P. CALVERT.
Committee.

RESOLUTIONS ON THE DEATH OF DR. HENRY SKINNER.

Dr. Henry Skinner died on May 29, 1926, at the age of sixty-five. He was a charter member and fellow of the Entomological Society of America, elected 2nd. Vice-President at the first meeting, presided at the second meeting and was elected President in 1908.

He became interested in insects as a young man and the butterflies in particular, following Dr. Samuel H. Scudder and Mr. William H. Edwards and carrying on their work as the outstanding authority on the North American Rhopalocera between the older group and the present young generation of students, equally well beloved of both.

His contributions to scientific literature were large and valuable, his first paper appearing in 1882 and his "Synonymic Catalogue of the North American Rhopalocera" in 1898. He was Editor of Entomological News from 1890 to 1910, President of the American Entomological Society from 1916 to 1925 and Vice-President of the Academy of Natural Sciences in Philadelphia since 1918, where he was Curator of the Entomological Department and an indefatigable worker until his death. His genial and kindly personality, his helpfulness to visitors and correspondents especially the encourgement and assistance he gave to beginners not only endeared him to all, but materially added to the ranks of the working entomologists.

The Entomological Society of America wishes to place on record its appreciation of this great scientist and courteous gentleman, deeply beloved by a host of friends at home and abroad.

(Signed) R. C. Williams Jr.,
J. C. Bradley,
P. P. Calvert.
Committee.

Professor Herbert Osborn next presented the report of the Committee on National Museum.

REPORT OF COMMITTEE ON NATIONAL MUSEUM.

At the meeting of the Society last year, "it was moved and the motion carried, that this Committee be requested to include as a supplement to each annual report a record of important additions to the Canadian National Collection and to the entomological collections in the various states." In compliance with this request, the Committee has sent to a number of Institutions where important collections are maintained, requesting information concerning the collections. It was thought best since this was the first report to include such matter that "it might be in place for each one to indicate briefly the main characteristics of the collection, possibly some data as to content, relative numbers in different orders, presence of type material and availability for use of members of the Society." The replies to this request have been quite generous and the following extracts from the reports submitted contain, we believe, the information which will be of particular interest and value to our members. No attempt has been made to arrange these in order of importance, alphabetically or geographically.

National Museum, Washington, D. C.—"It gives me much pleasure to deposit in the United States National Museum, as a gift presented in loving appreciation and honor of Dr. E. A. Schwarz, my collection of water beetles of the families Dytiscidæ and Haliplidæ, consisting of about 20,000 specimens, representing approximately 400 North American and perhaps 200 additional exotic species, including a few of the Fall types and a large number of cotypes and paratypes of the Fall species. This collection is in many ways the counterpart of both the Roberts collection of these beetles in the American Museum of Natural History and of the Blanchard collection in the Museum of Comparative Zoology, so that all three institutions now have fairly complete collections of the North American species of the beetles. My earliest interest in entomology was carefully fostered by Dr. Schwarz, to whom I was "turned over" by Prof. C. V. Riley and Dr. Howard almost forty years ago, and my own collection is principally the result of Dr. Schwarz's encouraging and guiding hand both at the start and in the years following." John D. Sherman, Jr.

From the National Musuem also it is reported that steel cases have been received for the permanent installation of the Casey Collection of beetles. Work on the labelling of the specimens has been progressing steadily, and a considerable portion of the collection is now in final form, through the interest and generosity of Mrs. Casey. Several visiting specialists, who have already examined some of these types, have expressed great pleasure in finding the collection so well taken care of. The Museum has recently received from Mr. Geo. M, Greene, Harrisburg, Penna., a collection of about 200 beetles, mostly from China and Japan.

Entomological Branch, Department of Agriculture.—The Canadian National Collection, has recently published an extended report upon the collections in the February, 1926, number of the Canadian Field Naturalist. The report is too extended to include here, but the following paragraph will indicate the extent of the collection.

"The National Collections of Insects is now contained in 31 steel cabinets of 1,550 drawers apportioned as follows: Lepidoptera, 625 drawers; Coleoptera, 250 drawers; Diptera, 225 drawers; Hymenoptera, 200 drawers; Hemiptera, 50 drawers; Orthoptera, 50 drawers; Odonata, 75 drawers; Ephemeridæ, 50 drawers; Neuropteroid insects (Partially unclassified), 25 drawers. There are besides two cabinets of alcohol material, including collections of Arachnida, Odonata and Ephemerida, and several slide-cabinets containing our material in plant-lice, fleas and thrips, etc."

"I might add that the chief addition this year to the collection besides the material coming in from our field officers, has been the collection made by myself in the vicinity of Lillcoet, B. C., amounting to 6,000—7,000 specimens. The number of species in the collection represented by type material at the present time is 2,358. Students of any order of insects are always welcome at Ottawa and are given every facility to carry on their research. In certain instances material is loaned to specialists working on monographic revisions."

J. McDunnough, *Chief.*

Museum Comparative Zoology, Cambridge, Mass.—The only large accessions in the past year were the Myers Salt Cuban Collection. The Curator's trip to Mt. Washington, and Dr. Wheeler's Morrocan Collection. The Collections include: *Arachnida*—Emerton types, Peckham Attidæ, Miss E. B. Bryant New England Coll., Chamberlain Coll., and Banks Coll. *Myriopoda*—Chamberlain Coll., Count Athems Coll. *Thysanura*—Packard Coll. *Neuroptera*—Hagen Coll., Banks Coll. (Over 2500 types, some over 100 years old). *Orthoptera*—Scudder Coll., Morse Coll. *Hemiptera*—No large collection. *Hymenoptera*—No large collection, but Osten Sacken, Cynipidæ, Dr. Wheeler's gifts of ants, and the Banks Psammocharidæ are notable. *Diptera*—Lower Coll., Osten Sacken Coll., (over 2000 types). *Lepidoptera*—Scudder butterflies, Treat Coll., Roland Thaxter Coll., Packard and Swett Geometridæ, Chambers and Dietz Microlepidoptera, and recently the bulk of the Jacob Collection (Presented by Mr. Cassino). *Coleoptera*—The Zimmerman Coll., Melsheimer and Ziegler Coll., the invaluable Leconte Coll. (with over 6000 types), the T. Blanchard Coll., Roland Hayward Coll., W. G. Dietz Coll., The Deyrolle Coll., of Rhynchephora and Cerambycidæ, The Harris Coll., of Cincindelidæ, the Bowditch duplicates in Chrysomelidæ (About 40 or 50 thousand specimens). Fossil insects—The famous Scudder Coll., and materials gathered by Dr. Hagen.

Much material was secured through expeditions, such as the Thayer Brazilian trip, the Uhler Hayti trip, the Thomas Barbour trip to the East Indies and elsewhere, the Mann trip to Solomon Islands and Fiji and Hassler expedition, and the Banks Panama trip. Insects have been obtained from many collectors, such as Wright in Cuba, Wright in Jamaica, Schwab in Kamerun, Boll in Texas and Kellerman in Guatemala, Goldsmith in Mexico, Steinbach in Bolivia, and hundreds of other lots.

The rooms are open every week-day, except in August, and the collections are available to any entomologist of standing; the Leconte collections only to specialists. Altogether there are types of over 19,000 species.

Nathan Banks, *Curator.*

New York State Museum, Albany, New York.—The New York State collection of insects comprises some 180,000 specimens representing all orders, the Lepidoptera and Coleoptera being especially well represented. We have probably the best collection in the world of Itonididæ (Cecidomyiidæ). There are approximately 1,000 types in the collections mostly of gall midges though there are a few in other groups. There is also a large amount of biological material. We have a number of small collections. The Fitch types described in his catalogue of insects collected and arranged for the State Cabinet of Natural History (Reprinted in the Ninth N. Y. Report). The Erastus Corning Collection of some 10,000 specimens. The J. A. Lintner collection. The last three are strong in Lepidoptera.

There have been no notable additions to our collections this season.

The Erastus Corning collection of Lepidoptera has been transferred to the custody of the New York State Museum by a recent vote of the Executive Committee of the Albany Institute and Historical and Art Society title of said collections however to remain with the Society. The Corning collection of Lepidoptera comprises somewhat over 4,000 specimens, the Sphingidæ, the Catocalas, and the Bombycidæ being particularly well represented. There are also a number of magnificent, exotic Lepidoptera, mostly Rhopalocera. This action places a magnificent collection where it will·be given suitable care and morever brings under one roof the work of three early, enthuiastic entomologists, namely, Messrs. J. A. Lintner, W. W. Hill and Erastus Corning, all co-workers in the latter part of the last century. The Lintner collection is particularly strong in the Noctuidæ, though it contains many other forms collected by Dr. Lintner during the earlier years of his entomological activities. The Hill collection comprises some 10,000 specimens representing over 3,000 types, the Nymphalidæ, the Lycaenidæ, the Hesperidæ, the Sphingidæ and the Noctuidæ being particularly well represented. An account of this last collection and a list of the species is given in N. Y. State Museum Bulletin 124, pages 61 to 117, 1908.

E. P. FELT, *State Entomologist.*

The Academy of Natural Sciences of Philadelphia, Philadelphia, Pa.—The collection of Lepidoptera includes the Skinner Collection of North American Rhopalocera with approximately 100 types, the Martindael collection of Exotic Lepidoptera and also many of the types of Grote, Blake, Mengel and others. In the Hymenoptera will be found almost all the types of Mr. E. T. Cresson, numbering about 2,600, many of those of Fox, Blake, Viereck and others, including the Bassett Collection of Cynipidæ.

The collection of Coleoptera includes that of Dr. George H. Horn with more than 67,000 specimens and over 1,500 types and also the Wilt Collection. In Orthoptera the collection includes around 500 types and the Hebard Collection, on deposit at the Academy, 1,086 types. In Odonata is included the important Calvert Collection. The collection of Diptera is large and particularly the Ephidridæ, in which Mr. E. T. Cresson, Jr., is specializing, includes many types. Large collections of most of the others are present but in many cases are largely unstudied.

During the present year, the R. C. Williams, Jr. Collection of Neo-Tropic Hesperidæ, including about 400 species and 2,500 specimens, is being included in the Academy Collection; and Dr. W. G. Dietz' collection of Tipulidæ has recently been presented to this institution. The growth of the collections is at present vigorous in the following orders in which active studies are being pursued by the following individuals; Lepidoptera (Rhopalocera) by R. C. Williams, Jr. and W. J. Coxey, Diptera by E.' T. Cresson, Jr. and Orthoptera by J. A. G. Rehn and Mr. Hebard.

MORGAN HEBARD, *Curator of Insects.*

University of Minnesota, St. Paul, Minn.—The insect collection here numbers about 400,000 to 500,000 specimens. The collection was established by Prof. Otto Lugger in the early days of the department and his collection still remains intact. It is especially rich in Coleoptera, practically all of which are determined. The Lugger collection is representative of the United States as a whole and includes many exotic forms. During the last twenty years many additions have been made to the collection and at the present time the orders Orthoptera, Hemiptera and Coleoptera are well represented with indentified material. The collection

contains the types of a number of Mutillidæ and considerable paratype material in the Miridæ. There is an abundance of unidentified material in the remaining orders. There have been no notable additions to the collection during the past year.
CLARENCE E. MICKEL, *Professor Entomology.*

Michigan State College, East Lansing, Mich.—Our collection here at the college occupies a special fire-proof building located near the laboratory and entirely accessible. It fills about 700 Harvard cases of which the contents of 600 are arranged and 100 merely named, but not worked into series. Besides these, we have of course, a lot of accessions, material not yet identified. We estimate the collection to contain between 25 and 30,000 species with the greatest numbers in Coleoptera and Lepidoptera. There are types here and there throughout the series, but no very great number. There are, however, many insects belonging originally to the Tepper collection and a good many insects determined by the older entomologists such as Cook, Riley, Leconte, Horn, etc.

We are always glad to allow specialists to compare material with our collection, but in the past the collection has suffered quite a bit from having material shipped abroad for examination.

R. H. PETTITT, *Professor Entomology.*

University of Illinois, Urbana, Ill.—The insect material at Urbana, Illinois, available for the use of members of the Entomological Society of American belongs to three independent units. There are the Illinois State Natural History Survey, the Natural History Museum of the University of Illinois, and the Dept. of Entomology of the University of Illinois. These collections are available to members of the Survey Staff for study, in keeping with the cooperative policy which also places the facilities and insect collection of the Survey at the service of the University.

The most important collection of insects is in the possession of the Illinois State Natural History Survey. This collection contains a few specimens dating back to the periods of William LeBaron (1870-1875) and Cyrus Thomas (1875-1882). However, to Stephen Alfred Forbes belongs the honor of really starting a collection of the insects of the state. The present collection, then, consists almost entirely of specimens collected since 1883. As a result of wise policy of many years accumulation and direct collection of insect material, the survey now possesses the most complete collection of Illinois insects in existence. The scope of the collection has never been definitely defined, but it's particular objective is to have a complete collection of the adult and immature insects of Illinois. No special attempt is made to secure exotics, but donations and exchanges of North American species are desired. The collection contains approximately 400,000 specimens, pinned insects, about 5,000 slides and 30,000 vials and bottles of material preserved in alcohol. The types in the collection are approximately as follows: 400 holotypes, 150 allotypes and 2,000 paratypes.

In addition to the material acquired by direct collecting, several collections of varying size have been acquired by purchase and incorporated with the collection of the Survey. The most notable of these is the first collection of Dr. W. A. Nason, acquired in the year 1908. Another collection of insects was obtained from the first president of the University of Illinois, S. H. Peabody, in 1891.

A complete list of the insect types in the Survey collection and a brief sketch of the latters origin and development is now in press. This will be sent to entomological workers on request.

The Natural History Museum of the University of Illinois possesses the Andreas Bolter and the second W. A. Nason collections of insects. Both of these collections were gifts to the University, the former in 1900 and the latter 1920. The Bolter collection contains a few types and about 120,000 pinned specimens from all parts of the world. The series of Coleoptera is particularly good. The second Nason collection contains about 25,000 miscellaneous pinned specimens and no types.

The Department of Entomology of the University of Illinois acquired the A. D. MacGillivray collection of Tenthredinoidea in 1924. This is one of the most important collections of saw-flies in North America and contains about 5,000 specimens and 400 holotypes. This collection is housed with the types of the Natural History Survey.

Practically all types stated *in litt.* to date to be in the collection of the University of Illinois or the University Museum should be credited to the Illinois State Natural History Survey. The latter organization was created by law, in 1917, by the merger of the State Laboratory of Natural History and the Office of the State Entomologist. Therefore, all types stated *in litt.* to be in the possession of the State Laboratory or Office of the State Entomologist are now in the Survey collection.

No especially notable additions were secured during the past year. Of course many specimens were received in exchange and by donations, including paratypes, but nothing that I would designate as "notable". Many thousand additional specimens were added by collecting in various parts of the state.

THEODORE H. FRISON.

Bureau of Plant Industry, Pennslyvania—The collection began about twenty-five years ago. At present it contains about fifty thousand specimens, and from eight to ten thousand species. Incorporated with this collection are the Daecke collection which is especially rich in Diptera; certain families of the Champlain and Kirk collections notably the Carabidæ; hemiptera and other material donated by Mr. J. G. Sanders; Florida specimens donated by Messrs. Knull and DeLong, and considerable western material donated by various collectors.

The Pennslyvania material has been collected by many workers who at one time or other have been connected with this Bureau, and has been identified by specialists in the various groups. A large part of the type material belonging to this collection was recently deposited with the U. S. National Museum. It is the policy of those in charge of this collection that all such valuable specimens should be deposited with that collection. The collection is always open for the use of any member of the Society or anyone else who is capable of appreciating its character, and making proper use of it.

T. L. GUYTON, *Chief Entomologist.*

Boston Society of Natural History, Boston, Mass.—The Society's collections are now strictly New England and the collection of insects contains about 8,500 determined species (over 50,000 specimens including some 550 types). Aside from this is the Harris collection (one of the oldest in this county) which contains about 5,000 species and 150 types.

C. W. JOHNSON.

Kansas State Agricultural College, Manhattan, Kan.—This department does maintain a good, strong, growing collection of insects. It has been kept in Schmitt boxes, but last year we adopted the tray system, as used by the U. S. National Museum. As fast as possible, we are transferring all determined material to the trays. We have three cabinets holding respectively 100,600 and 48,000 drawers of trays. We have adopted the U. S. National Museum sizes of trays, of which there are four, and their type of drawers. We will use the Schmitt boxes for duplicates and undetermined material.

The first contributions to the collection were made by Prof. A. E. Popenoe, head of the department of entomology from 1879 to 1908. In 1902 Prof. G. A. Dean, now head of the department began adding to the collection. Probably more specimens in the collection were given by him than by any other contributor.

The most important additions to our collection during the year were from collections made by Prof. J. W. McColloch on a trip to the sand dunes at Medora, Kansas, in July, and by Prof. McColloch and the writer on a trip to western Kansas and eastern Colorado in August. We attended the Pingree Park Conference. Of course, there is an annual accretion of several hundred specimens from collections made by students.

The collection includes about 3,500 species determined by specialists.

We have very little type material. There are several types in the Hymenoptera, but it is our policy to deposit types in the U. S. National Musuem. We have probably two dozen or more paratypes.

We are glad to have any person who is interested in the study of any group come here and use the collection. We have also been liberal in sending specimens to specialists for determination and study. We prefer not to send determined material and specimens already arranged in the Schmitt boxes or trays. It requires a great deal of extra labor and endangers specimens which we feel are very valuable.

I might stress the importance of the donation of the Knaus collection of Coleoptera. He is now arranging them in Schmitt boxes. When they are all arranged and determined, they are to be sent to this institution and the collections will be kept in fire-proof cabinets. The collection has already been formally accepted by the Board of Regents.

ROGER C. SMITH, *Professor of Entomology.*

Field Museum, Chicago, Ill.—Lepidoptera (Strecker Coll.)—This collection was made by Herman Strecker, Reading, Pennslyvania, and was purchased by the Museum in Sept. 1908. It consists of 24,166 butterflies and 22,546 moths (but no micros), as well as nearly 4,000 duplicates. In addition to the many rare species and abberations, it contains 251 types and paratypes representing 435 specimens described by Strecker, and Reakirt, Behr and others. The collection is still in the drawers and cabinets used by Strecker. *Lepidoptera* (A. J. Snyder Coll.)—A purchase made in June, 1904, and consisting of 5,564 butterflies and moths of North America and 409 exotic specimens. The collection contains a large series of Argynnids, in which Prof. Snyder was much interested, and a good series of Catocalas. About half of this collection has been transferred to better drawers, but the other half is still in the original drawers and cabinet. *Lepidoptera* (August Salla Coll.)—A gift received November, 1917, and consisting of 2,000 North American butterflies and moths, and several hundred beetles. The beetles are in their original glass topped drawers, and have very little data. *Lepidoptera* (J. G. Sorup Coll.)—A World's Fair collection which was purchased when the Museum was started and which has been on exhibition ever since. It consisted of about 3,000 specimens, now faded, of butterflies and moths of the world, but with practically no data. *Lepidoptera and Coleoptera* (George F. Curtis Coll.)—A donation received in March, 1914, and consisting of 16—specimens of butterflies, moths, and beetles, most of which are in poor condition and with very little data. *Coleoptera* (E. B. Chope Coll.)—This collection, purchased in August 1906, contains 10,819 specimens, representing 3,028 species, of North American beetles. Specimens have merely state labels and are still in their original boxes. *Coleoptera* (George P. Wells Coll.)—A donation received in Dec. 1900, and comprising about 6,000 North American beetles, most of which are without even state labels. It is preserved in the original book boxes. *Diptera* (Dr. Garry de N. Hough Coll.)—A twenty-year deposit made in December, 1920, by the University of Chicago. This collection of flies consists of close to 5,000 specimens, and is of considerable value in that it contains about seventy-five (when purchased by the University there were more) types of Anthomyidæ described by P. Stein, and also a few types of species named by Dr. Hough and Prof. Melander.

The acquisitions this year have been of the usual kind, varying from one specimen to three hundred and not being of any noteworthy interest. Mention, however, might be made of a gift from Dr. Lewis H. Weld of 221 galls and gall flies, of which all but thirteen are paratypes.

WM. J. GERHARD.

Massachusetts Agricultural College Department of Entomology, Our collections are, naturally, largely of New England material but with many specimens, particuarlly those of economic importance, from other parts of the country as well. As rapidly as we have been able to obtain and arrange them, all stages in the life history of the insect are added as an integral part of the collection and we have, protected in metal cabinets, about 1,000 specimens of types of varying rank, from holotype and allotype down to homotype. The main collection being necessarily, at a college like this, one which must be offered for general public examination at times, is kept in glass-topped trays and consists mainly of only two or three specimens of the adults, in addition to the early stages referred to. The remainder of the collection, however, is kept in part in trays and in part in Schmidt boxes, and there the material is, to quite an extent, in series showing variation, geographical distribution, etc.

Unfortunately, in too many of the groups, we have much unworked material, and we greatly need a curator, but we have thus far found it impossible to obtain permission from the State to engage one. We do a little something each year, however, in spare time, in the way of arranging, amplifying and improving. It would be impossible to give anything more than an estimate of the number of specimens in the collection, but I would make a guess that we have between 150 and 200,000 specimens. I nearly forgot to mention that we have quite a little material in the line of work of insects; e. g., work of bark beetles and such things, which, not lending itself to observation in trays, is kept for quite a part, in a museum case on shelves.

I do not think our collection is anything wonderful in any way, nor would it rate with the larger collections in the country by any means, but we do find it of a great deal of use with our students, and particularly certain trays, the material in which is brought together according to subject matter. Thus we have trays of the insects attacking vegetables, insects injurious to fruits, insects injurious in greenhouses, etc. These are in addition to the others previously referred to.

H. T. FERNALD.

Entomological Museum, University of Kansas, Lawrence, 1926—The entomological collections of the University of Kansas were started at the time of the foundation of the institution. This was due to the enthusiastic endeavors of Doctor Francis Huntington Snow, who in later years became Chancellor of the University. Doctor Snow, conducted many expeditions for the purpose of adding material to our entomological museum. With the Francis Huntington Snow collections as a nucleus the collection has been growing steadily to the present time. It now contains the following: North American Coleoptera, 9,000 species, 36,000 specimens; Lepidoptera, 3,756 species, 12,208 specimens, Diptera, 3,000 species, 7,845 specimens; Hymenoptera, 1,520 species, 4,000 specimens; Hemiptera, 900 species, 7,000 specimens; Homoptera, 725 species, 5,699 specimens; Orthoptera, 550 species, 2,000 specimens; Neuroptera, 350 species, 1,500 specimens; Coleoptera, 2,900 species, 8,500 specimens; Lepidoptera, 981 species, 1,716 specimens; Hemiptera, 5,000 specimens; Homoptera, 1,000 specimens; Duplicate collections for study, 250,000 specimens.

In addition to the above we have the following type material;

Neuroptera, 1; Orthoptera, 15; Hemiptera, 101; Homoptera, 85; Coleoptera, 14; Diptera, 582; Lepidoptera, 100; Hymenoptera. 276; African Diptera, 25; Coleoptera foreign, 14; Total, 1,223. The types include species described by Drs. Williston, Aldrich, Townsend, Snow, Cresson, F. X. Williams, Viereck, Lawson, and Hungerford, and Messrs. Curran, Robinson, Beamer and others.

H. B. HUNGERFORD.

The University of Nebraska, Lincoln, Nebr.—I warmly approve of the plan of recording annually the more important additions to the entomological collections of the various states, and will be glad to furnish the necessary information concerning the University of Nebraska collection.

This collection occupies an entire large room (208) in the fire-proof Plant Industry Building on the College of Agriculture Campus of the University of Nebraska, and the specimens are housed in mahogany drawers in steel cabinets identical with those in use in the U. S. National Museum. The collection contains approximately 400,000 specimens, and is particularly rich in exotic grasshoppers, crickets, mantids, walking-sticks, cockroaches and other *Orthoptera* (sens. lat.) assembled by Professor Bruner, as well as rich in North American Diptera and Hymenoptera, and in many families of the Coleoptera. Bruner's types of exotic *Orthoptera*: Williams' types of *Aphididæ*; Hunter's, Swenk's, H. S. Smith's and C. E. Michel's types of *Aculeate Hymenoptera* are well represented in the collection, which also has numerous types of sawflies described by Davis. Professor Bruner's collections of Mexican, Argentine and Philippine insects are also extensive, but largely unnamed. The collection is open for study by any responsible entomologist. During the past year there have been no outstanding additions to this collection.

MYRON H. SWENK.

Mississippi Agricultural and Mechanical College, A. & M. College, Miss.—In regard to our collection here at the Mississippi A. & M. College, there is not very much to report. As you know, our collection is chiefly a Mississippi collection. We have never made much effort to increase our collection of material from outside the state. There are a few groups in which special effort has been made to build up complete collections of Mississippi forms. I might mention especially the *Phyllophaga* (*Lachnosterna*), *Coccidæ, Cicadidæ, and Ipidæ.* So far as possible, we will be glad to send material to anyone who is interested in anything that we have here. R. W. HARNED.

The Connecticut Agricultural Experiment Station reports collections, mainly of Connecticut, with a total of over 6,000 species represented and including 131 types, 32 Conn. paratypes, and 25 paratypes not Connecticut and 6 co-types, the majority of these being in Hymenoptera.

Iowa State College, Ames, Iowa—The following additions have been made to the Iowa State Collection.

Faaborg Collection Lepidoptera purchased from Mr. J. S. Faaborg, Clinton, Iowa. Containing approximately 20,000 specimens and representing about 5,000 species; chiefly Nearctic and Palearctic forms but contains many from other regions. Collection of Miridæ presented to the Iowa State College by Dr. Harry H. Knight. Representing 353 species of which 268 are new additions to the Iowa State College collection and 143 species representing paratype material containing over 100 specimens and paratypes of all species of water-striders described by Drake. Collection of 100 species of Diptera from Dr. C. L. Fluke, Madison, Wisconsin. The collection contains a great number of Syrphidæ and has been determined by Dr. Fluke. The collection includes material which was assembled by Herbert Osborn for the college and C. P. Gillette, when he was Entomologist for the Experiment Station, and includes a series of types of Van Duzee Homoptera and the co-types of species described by Osborn and Ball. It is fairly complete for the Lepidoptera, Coleoptera, Hemiptera and Orthoptera for the state and includes some material from other localities. C. J. DRAKE.

Cornell University Insect Collection—The insect collections of Cornell University occupy over 3,000 cases 19 x 16 inches. Without having counted one may roughly estimate that they consist of somewhere between one and two million specimens. We have no count of the number of species represented in each order, but the relative size of the collection of each may be approximated from the number of cases devoted to it: Lepidoptera 800, Hymenoptera 580, Coleoptera 520, Diptera 300, Hemiptera 280, Odonata 170, Orthoptera 70, Neuroptera 50, Neuropteroid etc., 40, Trichoptera 25. The above estimates do not include the collection of Arachnida, which must rank as one of the two or three most extensive in this country. It is contained in what is estimated to be, between 20,000 and 25,000 vials. The collection is not limited to any geographical area, but particular emphasis is naturally laid upon the acquisition of the fauna primarily of New York State and secondarily of North American.

Out side of New York state material, besides innumerable lesser accessions from all parts of the world one may especially mention the following as sources of material each probably upwards of 25,000 specimens: Cornell University Entomological Expedition to South America of 1919-20, (100,000—200,000 specimens), Okefinokee Expedition of 1912-13, and other Ga., and Fla., material collected by J. C. Bradley during several years; British Columbia and Alberta material from J. C. Bradley 1905-1908; California material from J. C. Bradley 1906-07, 1914, 1915, 1917-19; Southern and Southwestern material from Cornell Biological Expedition of 1919; Heidemann collection of Hemiptera; R. J. Crew collection of Coleoptera. Of lesser extent, may be mentioned the Murtfeldt collection of Microlepidoptera, Sherman collection of Carabidæ, (640sp.) and extensive series of Hymenoptera from the Naturhistorische Museum of Vienna, 667 species of French spiders from Simon collection, about 1,200 species of exotic Hemiptera, (purchased), 730 species of N. A. Lepidoptera and Hemiptera from all regions from the Baker collection, collections of Chilean insects chiefly Hymenoptera from Alfredo Faz and from the Museo de Historia Natural of Santiago, of Argentinian from Carlos Read, of

Uruguayan insects from the Museo de Historia Natural de Montevideo. South America Hemiptera and Hymenoptera from H. L. Parish, East African Hymenoptera from H. Junod, an extensive Brazilean collection in all orders from A. G. Hammar; the sawfly collection accumulated previous to 1911 by the late A. D. MacGillivray, several thousand species of European insects of several orders purchased from time to time of Schniedeknecht, Konow, and from dealers. There have just been added about 250 determined and many undetermined Ithomiidæ and Danaidæ representing the personal collection of Fassl. Types of about 1,000 species have been catalogued, but the work is not yet completed. Every effort is made to make the collections available to persons engaged in scientific research, and members of the Entomological Society of America will be at all times welcome to make use of the collections. J. CHESTER BRADLY, *Curator*.

American Museum of Natural History—We have about 3200 species represented by type material. It is impossible to say how many other species we have but they are represented by about 1,000,000 specimens of which possibly 70% are identified either correctly or otherwise. They come from all parts of the world. All material is available for the study here by any member of the society but we do not loan types without the consent of the describer of the species.

FRANK E. LUTZ.

North Carolina State College—The college collection of insects consists chiefly of a collection of native and foreign Homoptera which is being arranged especially to show morphological relationships and is accompanied by a nearly completed index to the literature of the Homoptera of the world, now about 200,000 separate references to the genera and species. There is also a small general collection of the insects of all orders of North Carolina. Z. P. METCALF.

North Carolina Dept. of Agriculture—The Insect Collection of the Division of Entomology N. C. Dept. of Agriculture, is confined to North Carolina insects of all orders and their allies contains about 5,000 of the 7,500 species on record from the state and is contained in 750 Schmidt boxes. All the principal orders and most of the smaller ones are well represented in the collection.

C. S. BRIMLEY.

The collections of the Ohio State University include some quite extensive series of Lepidoptera and Odonata assembled by Dr. D. S. Kellicott. The Tallant collection of Lepidoptera, collections of Coloeptera and Orthoptera which are quite full for Ohio and extensive series of Diptera and Hemiptera which are largely the accumulations of material secured by Prof's. Hine and Osborn and the students who have worked with them.

(Signed) HERBERT OSBORN, Chairman,
C. W. JOHNSON,
WM. M. WHEELER,
JAS. G. NEEDHAM
Committee.

On motion it was moved that the report be printed in full. Motion carried.

After some discussion it was moved, seconded and carried that "a committee be appointed by the president to address a communication to the International Zoological Congress, expressing the views of the Society on certain questions in nomenclature; that this communication be based on a referendum to members of this Society." Committee appointed by newly elected president, Doctor Lutz, as follows: J. C. Bradley, Chairman, J. M. Aldrich and J. M. Swaine.

The meeting then adjourned.

Respectively submitted,

J. J. DAVIS, *Secretary.*

ANNALS

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THE MALPIGHIAN TUBULES OF THE LARVA OF HEPTAGENIA INTERPUNCTATA, SAY.

WM. S. MARSHALL,
University of Wisconsin.

The Malpighian tubules of the Ephemerida, both of the larva and the imago, have been described by a number of workers; as far as I have been able to ascertain there has not been any paper published in which one can find a detailed description of their structure either in the immature or the mature stage of these insects. These tubules in the May-flies assume, according to different observers, many forms; several have been described as filiform, others as similar in a general way to the ones described in the present paper. From both descriptions and figures it has been shown that in several species of May-flies the tubules are short and bent or coiled, or, in some species they assume a spiral form. The more detailed descriptions have shown that in many species each tubule consists of a distal, thicker and secretory, portion from which a thinner tube passes and enters indirectly or directly into the intestine. Tubules opening separately have been figured by Dufour (3) and Drenkelfort (2) but in most species it has been shown that they open into several common receptacula and that these open directly into the digestive tract; Leue (8) and Vayssiere (13). The short account of most of the quoted authors gives but a meager description; many, however, show the two above mentioned parts of each tubule and the spiral or twisted shape is commonly mentioned or figured. From these various accounts the one which most closely resembles the tubules of *Heptagenia interpunctata* is the figure given by Vayssiere (13) of *Heptagenia longicauda*.

In *Heptagenia interpunctata* there are eight tubes opening into the intestine and carrying the products of the Malpighian tubules; each of these, soon after its origin from the intestine, branches into two or three short and fairly wide tubes and these receive the ducts from the Malpighian tubules; there may be a secondary branching before the ducts are received. The number of tubules was not counted but there are many of them surrounding the intestine more being lateral than either dorsal or ventral. These eight tubes probably open into the intestine equidistant from each other although a couple of sections had the appearance of a lateral arrangement, four tubes entering each side. Drenkelfort (2) found that in *Siphlurus lacustris* there were more than a hundred Malpighian tubules.

Each Malpighian tubule is divided into a distal, secretory, part, the glandular portion, from which a tubular duct, somewhat longer than the active part, leads to one of the receptacula into which, as described above, they all have their outlet. The duct leaves the widest portion of the tubule near the center, really the end of the central coil.

The glandular portion of the tubule can, for the sake of description, be divided into two parts; there is first a long curved and bent distal arm which leads into the thicker and shorter central section from the end of which the duct leaves. This first arm is different in nearly every tubule but begins with a hook-like curve which, in some specimens, is more abrupt than in others. The terminal part of this hook is a little thinner than the rest but from the end the tubule gradually increases in diameter to reach its widest part just proximal to the beginning of the abrupt hook-like curve. This thicker part continues for about one-third the length of the tube which then gradually decreases in diameter. While but a single bend is shown in either the diagram (Fig. 2) or the drawing (Fig. 1) of the entire tubule this part rarely lies in one plane, even the hooked end, besides bending on itself, may also turn is some other way. The narrower portion continues for a short distance with only a slight curve and then the tube again turns abruptly on itself and for a short distance this part is more or less parallel to that portion of which it is a continuation. Soon after making this second abrupt curve the tube starts to make a spiral-like loop bending even more abruptly than either of the other turns, it also suddenly becomes very much wider; this is the beginning of the central portion. The increase in width in this central portion is very pronounced and, as it begins to abruptly widen, the tube turns sharply back on itself and so continues until it returns to where the wide central portion started; then it suddenly decreases in diameter to form the beginning of the duct. The duct then forms a nearly circular loop lying on the surface of the central part of the tubule and passing out to the convex margin of this portion, runs along this margin and returns to where it had its origin; here it leaves the tubule and goes to one of the receptacula already mentioned. These Malpighian tubules vary considerably in shape and size as also in their twists and turns so that it is extremely difficult to write a description of any one of them, they all, however, conform to the same general plan. Each tubule can be divided into a long distal arm, the wider central portion and the proximal part, the narrow duct. An examination of the drawing (Fig. 1) and the more diagrammatic representation (Fig. 2) will, aided by the description, give one an idea of the general shape and the relationship of the different parts.

Having thus attempted to describe the Malpighian tubule from a surface view we will give what the study of sections shows us about its structure. In nearly all of the tubules stained and mounted entire something of the lumen of the tube can be seen and it is noticed that this hollow is very much bent as it passes down the tube, it is large and irregular and varies greatly in diameter. Near the distal end of the tubule the form of the lumen is fairly regular and its structure that of a simple tube; the wall here, as in the other parts, is fairly uniform and of a single cell in thickness; the cell boundaries could not be seen (Fig. 3). From a surface view the nuclei, as in the cells of most Malpighian tubules, are quite large and are circular or irregularly so in outline; from an edge view they are oval and vary greatly in size. All the nuclei in this distal end are large.

In the next section of the tubule, from the commencement of the thinner part to the beginning of the second turn, the nuclei are smaller. In this part a surface view of the tubule often shows many of the nuclei of a kidney-bean shape and adjacent to their concave surface there can generally be seen a portion of the lumen. In a whole mount this section of the tubule shows for some distance the nuclei arranged in a single row; from a more careful study we see that there is really a double row of nuclei but that the alternate ones are in a different focus. In this section of the tubule the lumen shows a distinct wavy appearance the bend going from one side to the other; this is shown (Fig. 4) in section to be due to the fact that each nucleus with a small amount of surrounding cytoplasm projects out into the lumen and bends it towards the opposite surface; passing along the tube the next nucleus is seen to be on the opposite side of the tubule and the lumen bends in the other direction. This arrangement gives the tubule from a surface view the appearance of having the nuclei alternating with the clear spaces (Fig. 3, to the right).

Structurally the tubule shows no modifications until it widens into the central part; this change appears, in a whole mount, to be abrupt but in sections it is seen to be gradual (Fig. 9). The nuclei in that part of the tubule before it widens into the central portion are the same as in the preceding part and the lumen continues its course of alternating towards one side of the tube and then towards the opposite one. The lumen throughout this entire part of the tubule is not nearly so regular as is shown in the two figures (4 and 9), it often pushes out much nearer the wall and forms irregular pockets between the nuclei giving to some parts of the tubules, internally, a very irregular appearance; this is partly shown in the transverse sections (Figs. 5, 6 and 7).

The irregularities we have just mentioned in the shape and width of the lumen do not compare to what is found in the large central part where these changes in diameter are much greater. Here in both surface view and in sections it appears as if the hollow part of the tubule occupies, in sections, a large portion of the interior, or, in surface view it appears as large cracks between the nuclei. The cells of this central portion are larger than in any other part of the tubule but their nuclei do not show a corresponding increase in size. Sections through this central part if cut away from the center show the lumen as pockets pushing out between the nuclei towards the wall of the tubule (Fig. 10) and no doubt outlining the cell boundaries; or, nearer the median portion (Fig. 11) the true width of the lumen can be seen. We have already said that in the distal end of this central part the change from one part to the other was a gradual one (Fig. 9); at its proximal end, from which the duct arises, this is not the case and the change from the secretory part of the tubule to the duct is an abrupt one (Fig. 12). This change takes place near the concave surface of the central portion from which place the duct, lying on the surface of the central portion, passes to its convex margin near which it starts to turn and passes for some distance along the edge, then it gradually turns back again to near the place from which it started; in doing this it forms a loop and then passes away from the tubule towards one of the receptacula into which it opens. The duct shows no variation, except in width, throughout its entire length. From a surface view the nuclei are seen to be circular in outline and, in any one view, they often alternate from one side of the duct to the other; in many specimens each nucleus is seen to have a clear ring surrounding it (Fig. 14). In sections the wall of the duct consists of a thin layer of cytoplasm in which the nuclei, now seen from an edge view, are disk-like. Inside of this layer there is a thin lining, it often presents a shiny appearance as if it were cuticular.

A more detailed description of the tubule brings out some interesting points. The striated layer, rhabdorium, which is so characteristic for the mid-intestine and Malpighian tubules of insects is not present in the tubules of the larva of *Heptagenia interpunctata*, the adults were not examined and the presence or absence of this layer in the imago is not shown. Leue (8) in his work on the larva of *Heptagenia sulphurea* does not mention a striated layer and omits such a layer from his figure. McDunnough (9) working with *Chrysopa* found this layer in the tubules of the larva but not by the adult and Holmgren (6) records the absence of a striated layer in the Malpighian tubules of *Apion*. Most of the sections were stained only with Delafield's haematoxylin, a few were counter stained with Bordeaux red and in these it was quickly seen that the wall of the tubule, especially the central part, consists of two portions. The inner part of the wall bore the haematoxylin blue with a faint trace of the red but there was a fairly wide outer layer, widest in the middle of the central portion, which was of a much darker red; while best seen in the wide central portion this darker layer extended to near the end of the arm. This darker layer has been shown on only four of the figures, 9, 10, 12 and 13. In the sections stained with Heidenhain's haematoxylin the outer border was also noticeable and darker than the remaining part of the protoplasm. This is the external striated layer but, as in this insect there is no inner one present, the word external could well be omitted. This layer showed a number of elongated clear spaces at right angles to the basement membrane; these pass through the darker layer and give to it its striated appearance; these have been described as the canaliculi. In *Heptagenia interpunctata* they are very distinct in some specimens but not seen in others. This may be due to the different preserving fluids and stains used or to the time, relative to feeding, at which the insect was killed; than a stage in the activity of the tubule.

In very many of the tubules examined a second and smaller tube accompanied the duct and could be traced as far as the glandular portion of the tubule. This was probably a trachea to supply the tubule but a careful examination failed to show the presence of a taenidium; this might have been a tracheole from which the cuticular lining is absent.

The largest nuclei showed a pecularity in the presence in each of a large vacuole (Fig. 8) but never more than one in any nucleus.

A basement membrane is present as also a peritoneal covering, the latter can easily be seen especially so where the duct runs along the margin of the central body as this membrane lies external to the duct; it has not been drawn in any of the figures.

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EXPLANATION OF PLATE VIII.

Fig. 1. Surface view of a Malpighian tubule. × 280.

Fig. 2. Diagrammatic view of another tubule. In this and the preceding figure only a short piece of the duct is shown. Both figures show the long distal arm, the thicker central part and a portion of the duct including that part which forms a loop over the surface of the central body.

Fig. 3. Longitudinal section through the distal end of the arm. To the left the section is cut through the center of the tubule, to the right the section is almost a surface view. × 740.

Fig. 4. Longitudinal section of a portion of this arm taken from the narrower part. × 740.

Figs. 5, 6 and 7. Transverse sections through different parts of this armlike part of the tubule. All × 740.

Fig. 8. View of one of the large nuclei to show the contained vacuole. × 1700.

Fig. 9. Section through the proximal end of the arm where it enlarges to form the wider central part of the tubule, this latter portion is only in part outlined. Dt., duct. × 740.

Fig. 10. Longitudinal section of a part of the large central portion of the tubule. This section is cut between the center and outer surface and shows only in part the lumen which is represented by the five areas not stippled. Dt., duct. × 740.

Fig. 11. Another section, more median, of the same part. To the left the section is cut through the center of the tubule, to the right it is more of a surface view. × 740.

Fig. 12. The proximal end of the central portion showing the origin of the duct. Dt., transverse section of another part of the duct. × 740.

Fig. 13. Transverse section through the larger central region. This section as well as sections 9, 10 and 12 show the darker external striated layer. In this section, which is a higher magnification than the others, the canaliculi can be seen in this outer layer. × 1100.

Fig. 14. Surface view of a small portion of a duct. × 1700.

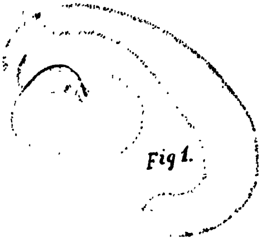


Fig 1.

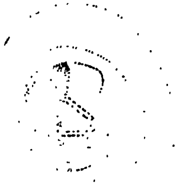
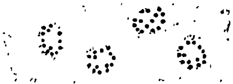


Fig 2.



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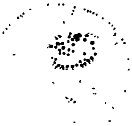

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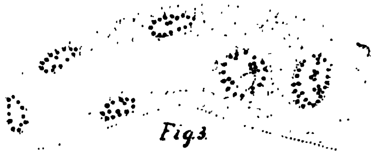
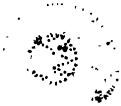


Fig 3.



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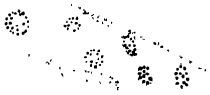
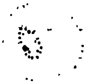


Fig 9.



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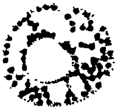

Fig 8.

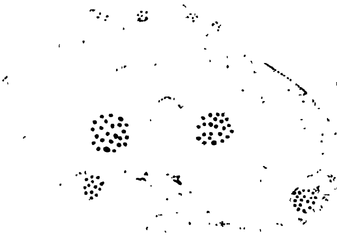

Fig 10.

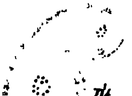

Fig 12

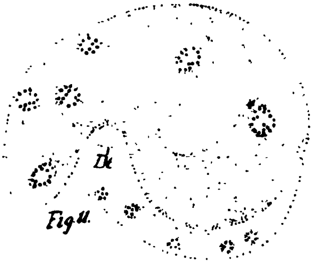

Fig 11.

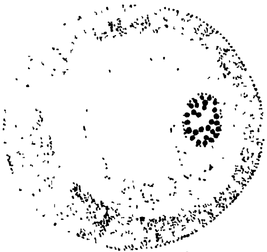

Fig 13.

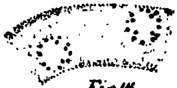

Fig 14.

Wm. S. Marshall

THE DEVELOPMENT OF THE CASTES OF BUMBLEBEES (BREMIDÆ: HYM.)*

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A. INTRODUCTION.

Published statements regarding the development of the workers, queens, and males of bumblebees are almost as varied as the total number of articles in which mention is made of this phase of their biology. Many investigators have touched upon this subject, but the writings of Reaumur (1742), Huber (1801), Lepeletier (1836) and Hoffer (1881-82) have exerted the greatest influence upon ideas which have attained more or less general acceptance. The most recent publications which give information concerning this subject are those of Sladen (1912) and Armbruster (1914). A review of this existing literature shows that many of the statements represent that which is purely inferred by analogy with the honeybee. Some statements are given which are based upon studies of bumblebee colonies, but unfortunately in most instances the observations were not thorough or frequent enough to prove the facts as they are stated.

The difficulty of absolutely tracing the life-history of a particular individual from egg to adult has been one of the chief obstacles leading to much of our misunderstanding of the life of the social bees. Although it has not been recognized, in some respects colonies of bumblebees offer a better opportunity than do colonies of honeybees for the study of caste and certain phases of sex determination among the social Hymenoptera. This is because bumblebee colonies are often so small that a close watch may be kept of the development of all the individuals and cells constituting a colony. In my experiments, the development of almost all the individuals of a single colony was often followed from the time when the first eggs were laid until the last adults emerged. Of course I do not mean to imply that all stages of all individuals in that colony were under observation every minute of the day; but merely that so many observations were made and such a close watch kept on all individuals that the results obtained would not be greatly modified by continuous observations. The difficulties standing in the way of continuous observations of social insects have been well pictured by Wheeler (1922). In this paper no attempt has been made to enter into a detailed discussion of the merits or weaknesses of the Dzierzon theory and the views of other investigators. It suffices for the present to state the facts, as I have found them, regarding the development of workers, queens, and males of bumblebees.

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B. CASTE OF PROGENY OF OVER-WINTERING QUEENS.

Let us first consider whether the over-wintering female bumblebee queen is capable of producing both males and females, without regard to the difference existing between females—workers and queens. In the light of that which we know to be true of insects in general, it may seem strange that there should exist any doubt as to this matter. The presence of certain small females—commonly referred to as workers—complicates such a problem as this in the case of the social bumblebees. Huber (1801) tells us that certain of the workers are surrounded by males produced in June and that these workers then become fertilized by these males and lay eggs which produce another brood of males. These latter males, in turn, fertilize the young queens which are produced in the latter part of the season. The fact that eggs laid by workers are generally assumed to produce only males is suggestive of the possibility that the males are entirely the product of worker eggs (Coville, 1890). In keeping with this view it is interesting to read recent statements of Friese (1922) that "die Eier für die Männchen von den grossen Arbeiten im Juli als unbefruchtete gelegt werden" and in another place that "In betraff des Verwandtschaftsverhältnisses würden demnach die Männchen eines Hummelnestes die Enkel der alten Nestmutter sein, die jugen Weibchen wie alle Arbeiter dagegen ihre Töchter sein."

Considerable evidence was found during the course of my studies in 1917-1920 that eggs laid by the over-wintering queens were capable of producing both males and females (workers and queens). This was found to be true in the case of several species (*B. vagans* F. Sm., *B. impatiens* Cress., *B. bimaculatus* Cress., *B. americanorum* Fabr., and *B. auricomus* Robt.) of bumblebees, colonies of which I had under close observation. The fact that workers (females) are the first bees—there may be occasional exceptions—to appear after the queens have established their nests in spring, is in itself almost sufficient evidence to prove that the queens produce these small workers of female sex. Further proof of this lies in the fact that many nests have been found in spring or early summer which contained only workers. Finally, my experiments in rearing colonies under controlled conditions leave no possible doubt of the fact that the over-wintering queens can lay eggs which produce females. Obviously, then, since the first progeny of over-wintering queens are normally, if not always, workers (females) our discussion has mainly to do with whether or not the queen is capable of laying eggs which produce males. As already indicated from statements in our literature, the occurrence of workers in the nests somewhat complicates the proof that the queens also produce males, even though it is that which we would naturally infer.

In my experiments ample evidence was obtained to prove that males were produced by over-wintering females or queens. In the first place, many of my colonies were subjected to two or three examinations a day and a detailed record kept of the number of eggs laid and the sex or caste of the individuals ultimately produced. In these experiments the condition of the queen was continually observed and a careful watch was made for egg-laying workers (unfertilized small females). It should be stated before going further with this discussion that egg-laying workers, as previously reported by others, do occur in the nests of bumblebees. By carefully checking up the number of eggs laid during the day, a good indication may be had of whether an egg-laying worker exists in the nest. Furthermore, the actions of egg-laying workers in a nest are so similar to those of queens relieved of almost all duties except egg-laying, that such workers are readily noticed by one acquainted with the habits of bumblebees. I have not found egg-laying workers, however, to be as common in the nests of bumblebees as some writers report, and in normal colonies which possess an active laying queen, few workers become egg-layers during the fore and middle periods of the existence of the colony.

In many experiments where it was reasonably certain that egg-laying workers were not present, and that the queens were functioning at a normal rate for their species, eggs laid by the over-wintering queens produced males. Under normal conditions in temperate climates a queen does not lay eggs which produce males until a goodly number of female eggs have been laid. The time at which the male eggs appear in a normal colony of bumblebees has somewhat of a correlation with the fecundity and the seasonal adjustment of the species. Queens of *Bremus bimaculatus* have a comparatively low fecundity and a restricted period of productivity. In such a species as this, the eggs which produce males may be laid by the queens the last of May and not infrequently in June. In the case of *Bremus americanorum* and *Bremus impatiens* we have queens with a comparatively high fecundity and a long seasonal adjustment. The queens of these latter species usually do not lay eggs which produce males until the middle of July, and the larger number of them are laid in August.

The fact that males and queens come from cocoons in the same cluster or unit group has been cited as proof that both males and queens are produced by the mother queen. This may not be the case, because larvæ originating from several egg cells may eventually merge and form one group of larvæ (they may be of the same size or different in size) as Wagner (1907) mentions and as I have often observed. It might be assumed, also, that the adults reared from eggs laid in a single cell would prove whether males and females are both produced from eggs laid by the queens. It has been my experience, however, that most of the eggs laid at one time and in the same cell produce adults of the same sex. In Experiment 6, 1919, (*B. impatiens*), over two hundred eggs were laid which produced workers (females), before any eggs were laid which produced males. Sladen (1912) has mentioned that in some nests he had under observation that no males were ever produced. In view of such conditions as these, it is evident that statements based on the observation of few egg cells might easily lead to erroneous conclusions. Males and females which are the product of eggs laid in the same cell (sometimes this happens) are most frequently found during the "climax" period of the development of the colony. This, naturally, is due to the fact that almost all of the eggs laid in the early history of the colony are of the same sex and that those laid at a later date produce the males and females. Armbruster (1914) even questions whether rearing males and females from eggs in the same cell proves anything, because of the fact that workers might be responsible for some of the eggs (the male eggs). In my experiments I have never seen workers open a closed egg cell and lay eggs in it or attempt to lay eggs in the same cell in which a queen was laying eggs. According to my experience, a queen never opens a closed cell for the purpose of laying additional eggs in it and I am extremely skeptical as to whether the workers have any such instinct and thereby differ from the queen. Hoffer (1881-82) has made a statement to the effect that queens do lay eggs at intervals in the same cell, but my observations indicate the contrary. Wagner (1907), also, has questioned the correctness of this statement by Hoffer. Certainly, if such an event ever occurs it is the exception rather than the rule.

The fact that in my experiments males developed from eggs laid by queens, when no evidence existed indicating the presence of an egg-laying worker in the nest, makes it obvious that eggs laid by the queens are capable of producing males. Lastly, it can be added that in certain of my colonies I have actually observed the queens lay eggs which eventually produced males. This corroborates the opinion of Hoffer (1881-82), who (aside from certain other statements) emphatically states that the queens can lay eggs of all castes. Sladen (1912) also credits the queen with producing both sexes. If workers alone were charged with the responsibility of producing males, there would be need of some sort of further specialization among bumblebees to prevent all workers from assuming this function, if the colonies were ever to attain large size and preserve a reasonable proportion between the female and male castes. The abundance of egg-laying workers in a normal colony seems to me to have been over-estimated, and the observations indicating such conditions based upon colonies whose natural routine had been greatly disturbed. My experience with egg-laying workers has been in the main quite similar to that of Sladen, who writes that "unless the queen is unprolific, or dies early, the workers produce very few offspring, indeed in many nests they produce none."

In the arctic regions only small colonies of bumblebees are developed because of the short season, but nevertheless males are quite abundant. In fact, workers of some of the most northern species are much less common than are the males. Sparre-Schneider (Friese, 1902) failed to find the workers of one species of bumblebee, *Bremus kirbyellus* (Curtis), during a long residence in the arctic regions, and the workers of another species, *Bremus hyperboreus* (Schönheer), were extremely rare. These facts, though not conclusive (the workers may have remained in the nest, etc.), strongly indicate that queens produce both males and females. In the case of the social parasite *Psithyrus*, likewise a member of the Bremidæ, both males and females are produced by the over-wintering females as is indicated by the fact they emerge about the same time. The production of the males, in such a case as this, can be explained in no other way than that they were produced by the over-wintering females.

C. CASTE OF THE PROGENY OF EGG-LAYING WORKERS.

Granting that the queens which establish colonies in spring produce males and females, the question now arises as to the occurrence of egg-laying workers and the sex of the individuals which result from such eggs. The presence of egg-laying workers in nests of bumblebees has been observed by Huber (1801), Lepeletier (1836), Schmiedeknecht (1878), Hoffer (1881-82), Sladen (1912), Armbruster (1914), Bachman (1915), and Plath (1924), and reference to their presence has been mentioned by many writers. During the course of my studies it has been my good fortune to obtain considerable information relating to workers which lay eggs. My proof that workers lay eggs is based on the fact that I have dissected certain worker suspects and found eggs in their ovaries, seen workers lay eggs, and studied colonies where the conditions were such that the eggs which were laid could only have been laid by workers. In one colony of *Bremus bimaculatus*, Experiment 1, 1919, six workers were discovered to have assumed the roll of egg-layers a few days after the disappearance of the queen from the nest. In this nest a worker was once observed in the act of laying eggs in a cell which she had just made. The instinct of making egg cells is not suddenly developed in the workers because workers were frequently seen which I had no reason to suspect as being egg-layers, aiding the queens in the construction of egg cells in which the queens later deposited eggs. The six egg-laying workers found in Experiment 1, 1919, were the most ever observed at one time in a single colony. Within a period of thirteen days, these workers laid nearly fifty eggs. From one to three eggs were laid in a cell. The only difference that I could see between these eggs and those laid by the queen was that they were smaller. The same was true, also, of the size of the eggs cells.

As already stated, egg-laying workers are usually not found in nests during the early part of the development of the comb. In the case of *Bremus bimaculatus*, the colonies of which early reach their "climax" development and produce males and young queens in June and July, egg-laying workers were found as early as June. In a colony of *Bremus impatiens* which produced a majority of its males and young queens in August and September, egg-laying workers were not found until September. In a colony of *Bremus vagans* seven eggs were found one day which had been laid in an irregular manner in an old male cocoon, partially filled with pollen, and capped on top with a composition wax-pollen covering. There was abundant evidence to prove that these eggs were laid by a worker. Without going into further detail, it is sufficient to record that egg-laying workers also were observed in the nests of *Bremus americanorum*, *Bremus auricomus*, and *Bremus separatus* (Cresson). The fact that I have observed egg-laying workers in four different subgenera of *Bremus* is quite indicative that parthenogenesis is not confined to any particular group of bumblebees. It is easy to demonstrate that workers can lay eggs by removing several workers from a nest and placing them in an artificial nest exactly like that provided a queen in spring. Under such conditions workers will frequently make egg cells and lay eggs. Plath (1924) has likewise found that workers will construct egg cells and lay eggs when deprived of a queen. Whether females of *Psithyrus* which have not been fertilized are capable of laying eggs has not been established, but in view of what has been found true of *Bremus*, it is not improbable. The seasonal adjustment of the species in temperate regions, however, is such that parthenogenesis can not play an important part in the development of the males of *Psithyrus*.

As stated before the presence of numbers of egg-laying workers in a colony, judging from my observations, is certainly abnormal. Furthermore, the presence of egg-laying workers seems to be correlated with the failing fecundity of a queen, the loss of a queen, or other conditions which are leading to the demoralization and disintegration of the colony. For instance, in Experiment 6, 1919, (*B. impatiens*) egg-laying workers were not noticed until after the death of the queen on September 7. In Experiment 11, 1917, (*B. bimaculatus*) workers removed from the colony and placed in nests with young queens developed egg-laying habits. This was evidently due to the abnormal conditions to which the workers were subjected. An excellent illustration of the effect that the loss of a queen has upon workers in respect to egg-laying was shown in Experiment 13, 1917, (*B. bimaculatus*), and other examples of similar nature might be cited. In colonies which have comparatively very prolific queens, many adults are produced before males appear or before egg-laying workers are found in the nests. In Experiment 6, 1919, (*B. impatiens*) over two hundred workers were reared before any males appeared, which indicates that there is something about the presence of an active and prolific queen which prevents workers from playing a prominent part in egg-laying. The same condition is noticeable in strong colonies of *B. americanorum*, which may produce a couple of hundred workers before any of them are found trying to act the part of a queen. If one removes the queen of *B. americanorum* from a nest before many workers have been reared, certain workers will soon lay unfertilized eggs.

An egg-laying worker may be readily detected by her worn appearance and actions. The presence of small egg cells and but few eggs in a cell (where the queen has the habit of laying many eggs in a cell) are likewise good indications of the presence of egg-laying workers. Queen bumblebees which are mothering a colony often look quite different from the new queens in the fall. This is because the abdomen of such a queen becomes somewhat distended and much of the pubescence on the head, thorax and abdomen may be lost. The same condition is noticeable in egg-laying workers. Of course, workers not laying eggs may lose some of their pubescence, but the distended abdomen of an egg-laying worker is quite characteristic and noticeable. The habits of egg-laying workers are quite similar to those of queens after they have quit foraging for nectar and pollen. Accordingly, such workers remain in the nest most if not all of the time and crawl about and brood on portions of the comb, particularly upon cells containing their own progeny. When colonies containing such workers are disturbed, these egg-laying unfertilized workers buzz excitedly and race about over the comb, but rarely fly forth in its defense. The fact that these laying workers so closely mimic in their actions the larger queens may be the reason why all workers do not become egg-layers when the queen fails. . In other words, the first few workers to start laying eggs and assume the roll of queens may serve in a measure to prevent other workers from taking on this function. I have never seen more than six laying workers in a nest at one time.

Reference has already been made to Huber's idea that certain workers are fertilized by males produced in June, and that the males resulting from this union mate with the young queens. Our earliest american student of the biology of the bumblebees was skeptical of this notion (Putnam, 1865) and nothing has been found in the course of my studies to indicate that such an intricate and indirect system for perpetuating the species of bumblebees exists. Many reasons could be advanced to seriously discount Huber's statements and mention will here be made of several of the most obvious ones. In the first place no males occur in most nests sufficiently early in the season to fertilize the first so-called small queens (workers). Secondly, I have never seen males mate or attempt to mate with small workers at any time. Though such a thing may happen, it certainly is of rare occurrence (Sladen reports one instance of this). Lastly, if these workers are fertilized by males, why do all the resulting progeny happen to be males? Though it seems to me that Huber is entirely wrong in his indirect system of queen fertilization, I am not challenging the idea that males resulting from worker eggs are capable of fertilizing young queens. Males reared from worker eggs have never been observed mating with young queens, but there is apparently no reason why they are incapable of doing so. No morphological differences between males reared from worker eggs and males produced from eggs laid by queens were apparent.

Granting the fact that certain workers lay eggs, we are now confronted with the question as to whether these eggs produce adults, and as to their sex. Most biographers of bumblebee life mention that the eggs laid by unfertilized workers produce males. In view, however, of the careful and continous observations which are necessary to definitely prove this point and the methods of study pursued by previous writers, it seems that most of these statements rest upon very little real evidence. Though as stated, most previous writers have held the view that worker eggs produce only males, we find such an able and keen investigator as Hoffer maintaining that under certain circumstances large workers (Hoffer calls them small queens) lay eggs from which workers, queens and males develop. He fails, however, to tell the circumstances which bring this about and whether these particular females are fertilized or not. Schmiedeknecht has mentioned also that large workers now and then hibernate and states he believed that they were capable of starting colonies. Schmiedeknecht's statements may be dismissed as mere opinions, and furthermore the bumblebees that Schmiedeknecht considered as large workers may in truth be entitled to be classed as queens of less than average size. It should be stated here that young queens collected in fall nearly always appear smaller than queens found in the field in spring. This is because the abdomens of queens are more distended in spring than before hibernation. Furthermore, as will be presently pointed out, it is a question just where to draw the line between large workers and queens.

In my experiments, all adults unquestionably reared from worker eggs were males. In Experiment 5, 1917, (*B. bimaculatus*) the mother queen died during the last of July. Workers soon began laying eggs and several males emerged between September 6 and 8 which were the product of these worker eggs. The same thing happened in Experiment 13, 1917 (*B. bimaculatus*). In every case that came under my observation the adults reared from worker eggs produced males. The same objection against claiming on the basis of these data that all worker eggs of bumblebees are of male sex can be advanced in this case as has been done against similar rearings of males of *Apis mellifica* (Linn). In my colonies of bumblebees, the greatest part of the eggs laid by workers failed to produce adults and accordingly the sex of the eggs which failed to develop is unknown. However, no evidence was found that any workers or queens were ever developed and accordingly no evidence discovered to support Hoffer's statement that under certain conditions worker eggs might produce females. In view of my studies I believe that all adults originating from unfertilized workers (such was the condition of the workers in my experiments) are males. That the european species studied by Hoffer are not much different biologically from the species occurring in Illinois will be brought out in another paper. Sladen, who studied many of the species studied by Hoffer, says that there is "ample evidence to show that the laying workers are virgins, and this explains why they produce males only." Armbruster (1914) also says that the eggs laid by workers of *B. pratorum* (Linn.) produce males. Though most of the eggs laid by workers in my colonies failed to produce adults, the conditions in my colonies at the time the egg-laying workers appeared and when eggs were laid were such that an explanation of their failure to produce adults does not necessarily lie in theoretical realms. As already stated, egg-laying workers in a colony of bumblebees are usually the sign of the failing prolificness of the queen, her loss, or the general disorganization or disintegration of the colony. The death rate of ordinary workers rapidly reduces their number after a colony has reached a stage where no more females are produced. This, coupled with the fact that workers with egg-laying propensities are strongly inclined to remain in the nest and not forage for provisions, normally hinders the rearing of adults from worker eggs. Often, even the young progeny of a failing queen, or those of a queen which has recently died, may succumb to the unfavorable conditions resulting from such a condition. The theoretical assumption, however, that some eggs laid by workers fail to develop because of inherent conditions is still not entirely eliminated. Certain experiments aiming at the rearing of a greater proportion of worker eggs are being planned by the writer.

D. INFLUENCE UPON SEX BY LARVAL FEEDING AND EGG-CELL.

Considerable evidence was obtained that larval feeding was not responsible for sex. There are but two ways by which such differences as exist between males and females can arise: either the eggs are inherently male and female when they are laid or the larvæ are reared under conditions which influence the developmental stages so that either one sex or the other is produced. In the case of bumblebees the only environmental factor which could possibly exert such a marked influence would be feeding, since all the other factors are practically the same within the nest. In fact, male and female bumblebees develop side by side under similar conditions of temperature, humidity, position on comb, etc. That quantitative feeding does not determine the sex of bumblebees is indicated by the fact that in my colonies adults of one particular sex did not invariably result from undernourished or poorly cared for larvæ; and the reverse of this, that highly nourished and well cared for larvæ do not invariably produce adults of the same sex. Small or even tiny males are sometimes produced in a nest of bumblebees as well as various sizes of females. When males much below average size were reared it was found that the larvæ which produced these males had been invariably subjected to unfavorable conditions which caused the larvæ to receive insufficient nourishment. For instance, diminutive males were often reared from larvæ whose cells occupied a position on the comb less frequently visited by workers than certain other parts. Small males were also encountered in nests when a colony had become disorganized and was breaking up, a condition which resulted in the larvæ existing in the nest at the time not being properly supplied with food at all times. I have reared under-sized males from colonies of *B. impatiens*, *B. bimaculatus*, *B. vagans*, *B. separatus*, *B. auricomus*, *and B. americanorum* and in all cases the cause for their development could be diagnosed as malnutrition. In figures 1, 2, 3, and 4 are shown the range in size of males of the same species. Though the males of any species of bumblebee produced under average conditions have about the same general size, all different sizes as just pointed out, may occur within the same nest. When we consider the evidence presented by parthenogenesis and that which is given under a discussion of the cause of polymorphism in females, there seems slight doubt but that males and females result from differences in the character of the eggs and that sex is not influenced by feeding, environmental conditions, etc.

In connection with the problem of sex determination in the case of the honeybee, it has been stated that the size of the cell influenced sex. No difference was observed in the shape or size of bumblebee cells which (as shown by subsequent rearings) held potential male and female eggs. Furthermore, as already mentioned, males and females sometimes developed from eggs laid in the same egg cell. Such an explanation as the size or shape of the egg cell can therefore be easily eliminated as a factor influencing sex among bumblebees.

E. CAUSE OF POLYMORPHISM AMONG FEMALES.

I have repeatedly studied large series of queens and workers (females) of various species and have failed to find any pronounced structural differences between the forms of the same sex such as are found in the case of ants and termites, and to a less extent usually between the queens and workers of *Apis*. In fact, the only discernible external difference is one of size. Physiologically and psychologically the workers are apparently nearly duplicates of the queen, since they possess almost all of the instincts of a queen, are capable of doing most of the things she does and are even capable of laying eggs which produce adults. Hence, polymorphism as it finds expression among the bumblebees, has mainly to do with size. Of course, the time and circumstances attending the production of the small workers causes certain elements of their behavior to stand out more sharply than those of the queen. Thus, the small females appear to be more specialized for foraging for pollen and nectar and for caring for the nest in general,—hence the name *workers*.

Workers are commonly spoken of as forming two classes, namely, large and small workers. Such a division is purely arbitrary with the recorder, for almost every possible variation exists in size from the smallest to the largest workers, and often in the case of some species to the over-wintering females called queens. In other words, the terms large and small worker, as applied to bumblebees, are simply convenient descriptive terms for use in describing the size of females which are not large enough to be called queens (therefore not capable of establishing normal new colonies). One might with propriety list the workers found in a single nest as tiny workers, small workers, large workers, very large workers, and so on. In my own papers the practice has been followed of simply referring to workers as forming two main overlapping artificial groups: large and small workers. Also, the term *queen* has been used solely to refer to those females which are capable of mating, hibernating and of producing new colonies and adults of both sexes. In figures 1, 2, 3, and 4 are shown a series of workers of various sizes of different species and also females which have attained sufficient size to be considered as queens.

If we grant that males and females of bumblebees result from a hereditary influence, the question arises as to whether the polymorphism witnessed in bumblebee females is hereditary. We now know that in certain groups of social insects, as termites which have developed an elaborate caste system, that the castes may be determined to a certain extent in the egg stage. The same is said to be true of the ants. In the case of *Apis mellifica*, it has been demonstrated that eggs laid in queen cells, which under normal conditions would produce queens, if transferred to worker cells produce workers and *vice versa*. Even very young larvæ may be transferred with the same results as those obtained by the transfer of eggs. This is accepted as proof that in the case of the honeybee the difference between queens and workers (both females) is due to trophogeny. Mention has already been made of the fact that in the case of the bumblebees I have not been able to detect any differences between cells in which male and female eggs are laid. Accordingly, without a discernible difference in the size of the egg cells as a starting point for experimentation, the transference of eggs from one cell to another would be meaningless. Eggs can be transferred from one cell to another, however, as I demonstrated in certain colonies; even the eggs of another species of bumblebee. Many other facts have been found, however, which strongly indicate, if not actually prove, that the polymorphism of female bumblebees is due to feeding and that workers are merely miniature unfertilized queens.

As already stated, the females conveniently designated as workers vary greatly in size (See Figures 1, 2, 3, and 4). This variation is so great that there often may be produced in the same colony in the course of the season a complete transitional series from the tiniest female (worker) to the largest female (queen). In the course of my experiments in rearing colonies of bumblebees of various species belonging to different subgenera from their beginning to "climax" development, it was always observed that the first workers (females) produced were comparatively small, and that workers averaged larger and larger as the season progressed. Any number of my experiments might be cited to illustrate this point. As a single illustration of this a part of the history of Experiment 11, 1917 (*B. bimaculatus*) will be related. The colonies of this species usually reach their "climax" development in Illinois in June or early July. In this particular colony the average size of the workers increased with almost every succeeding period of emergence. Finally there came a time, shortly after the middle of June, when it was difficult to determine whether I was dealing with young queens or large workers. This was immediately followed by the production of females of such large size that there was no question as to their being queens. In fact, subsequent mating and hibernation experiments proved that they were queens. This might have been considered as a case of coincidence if it had not been a matter of such general occurrence in my colonies. Of course small individuals were produced even in the middle of the season, but being few in number they did not affect the gradual increasing average in size. Such small workers produced in mid-season were usually found to have developed upon unfavorable parts of the comb. Colonies facing disintegration before their "climax" development is reached can not be considered in relation to this subject because they do not represent normal conditions.

To explain such variations in size as mentioned (Figs. 1, 2, 3, and 4) we must either assume a large number of differentiated eggs or the effects of environmental conditions. The fact that adults varying in size are produced from larvæ from the same egg cell; that female larvæ occupying an unfavorable position on the comb produce small workers; and that unfavorable conditions in the colony as a whole may cause small adults, all indicate that environmental conditions are responsible for the polymorphism exhibited by female bumblebees. Furthermore, the very number of different sizes of workers is sufficient to cause one to hesitate to ascribe the type of female polymorphism (size, not difference in structure) exemplified by bumblebees as being due to inherent differences in the eggs. As already brought out, the difference in the size of males is likewise due to conditions exerting an influence after the egg is laid—the result of feeding.

When we consider that tiny workers are reared from female larvæ as a result of malnutrition, the reverse conclusion, that the abundance of proper food causes the production of large workers, is not illogical. A close study of colonies of bumblebees indicate that the production of large workers is due to feeding. The first workers are developed by the queen without the aid of workers. After the appearance of the first workers, the queen is aided with the rearing of the brood and in foraging by the workers. As the season progresses the workers become still more numerous and a surplus of honey and pollen is often found in the nests at this time. In other words, the increase in size of workers is correlated with conditions which suggest that the amount or quality of food is the factor which determines whether a female egg will produce small workers, large workers, or queens. Bumblebee larvæ are fed on pollen and a liquid which is supplied them from time to time by adults. The fact that the adults actually feed the growing larvæ from time to time, instead of entirely allowing the larvæ to develop in sealed cells containing food (mass-provisioning) is another feature suggesting that the size of females is due to feeding.

In order to properly conclude my arguments that feeding, either qualitative or quantitative, is responsible for the variation in the size of female bumblebees, I must introduce at this place some data regarding the fecundity of queens. I have found that *B. auricomus*, in Illinois, does not produce large colonies of bumblebees and that the chief reason for this is the low fecundity of the females. This low fecundity prohibits this species from producing a very numerous worker caste, but neveretheless large workers and queens are produced. There are other species in this state, however, which possess a comparatively high fecundity. This difference of various species in respect to fecundity is such, figuratively speaking, that a series of species from an extremely low to a relatively high fecundity may be arranged. The important point about such a series is that it is a transitional series and that high fecundity is associated with species producing queens after the appearance of numerous workers.

Though the biology of the bumblebees living in artic regions is not well known, my studies (Frison, 1919, 1921, 1922) of various collections of bumblebees from Greenland and the arctic regions of North America show that the worker caste is reduced in numbers. No species is known, however, which does not produce workers. As previously mentioned, Sparre Schneider in Tromso, Norway, after many years of collecting failed to find workers of *B. kirbyellus.* Workers of this species are known, however, from arctic Eurasia and America. I have seen workers of this species from various parts of its range, but nevertheless the worker caste is truly reduced in numbers. In the arctic regions the season of bumblebee activity is short and the young queens are apparently oftentimes reared directly by the mother queen without the aid of an intermediary worker caste. This at first thought may seem to present a formidable obstacle in the path of the contention that feeding determines the development of the workers and queens. Such, however, is not the case. The small size of colonies of arctic species of bumblebees indicates to me a low fecundity of the queens, a state of affairs found to exist in the case of certain bumblebees in temperate climates which produce but small colonies. The very shortness, also, of the season which is favorable for brood rearing necessitates a low fecundity on the part of the queen. When we consider the time that is required for the development of the immature stages of bumblebees, the amount of food consumed by the larvæ, and the constant care they require (not necessary in mass-provisioning), a high fecundity on the part of the queen would be disadvantageous to arctic bumblebees. In order to cope successfully with their envirnment the arctic bumblebees must of necessity concentrate on rearing a few instead of many progeny, and evidently these larvæ receive the food and attention which larvæ of certain species with a high fecundity in temperate climates, as Illinois, usually receive after the production of a numerous worker caste. Though not forced by climatic restrictions to have a low fecundity, certain species of bumblebees with a low fecundity found in temperate climates evidently concentrate upon rearing a few individuals, some of which are queens, much after the manner of their northern relations.

Degree of fecundity, then, offers an explanation of the production of numerous workers by some species and only a few workers by other species. Furthermore, it enables us to explain the production of queens in all climates, and of all species inhabiting similar geographical areas regardless of any differences these species may exhibit in regard to the number of individuals produced.

A comparatively long time between periods of egg-laying and the laying of but few eggs at a time (attributes of low fecundity) results in the queen, and later the workers, having more time to care for the brood than is possible where eggs are laid more frequently and in larger numbers (high fecundity). A prolific egg-laying queen of *B. impatiens* or *B. americanorum* during the last of July and early August can not possibly devote much time to her numerous progeny and they are mainly reared by the workers. When a queen bumblebee becomes merely an "egg-laying machine", as in the case of the queen honeybee, no or little time can be spent caring for her progeny. In such a case, then, it is logical to suppose that new queens will not be produced until an abundance of nurses and bountiful food supplies are present in the nest. Such seems to be the case and indicates that food or feeding governs the production of new queens.

No analytical studies of the liquid food supplied to bumblebee larvæ by adult bees were made. In the case of the honeybee, it has been established that a larva producing a queen is fed for a longer time more highly proteinaceous food than the larva of a worker and develops in less time than a worker. With the bumblebees on the contrary, the larvæ producing queens have a longer larval stage than do the larvæ producing workers. The proof of this statement will be presented in another paper. This suggests that in the case of bumblebees the difference between workers and queens may be due to quantity alone, rather than to a difference in the quality of the liquid food inserted into the larval cells. Structurally and biologically bumblebees display evidence that they are a group still in the course of active progressive evolution. In this connection it seems worth noting that there exists a greater average difference in size between the queens and workers of *B. impatiens* than with any other species of bumblebees that I have studied. This is correlated in this species with queens which have a very high fecundity and suggests that this species presents a rudimentary specialization of the more highly developed caste system of the honeybee.

F. CONCLUSION.

As is well known many theories have been advanced to explain the question of sex determination in the case of the honeybees. The theory of Dzierzon that male honeybees develop from unfertilized eggs has met with considerable favor but Dzierzon's idea that all the eggs in the ovaries of the female are male has not met with equal approval. My rearings of male bumblebees from eggs laid by unfertilized workers agrees with that part of the Dzierzon theory which states that adults reared from unfertilized eggs are males. Additional experiments are planned with bumblebees to determine whether all eggs laid by unfertilized females are of the same sex (male). In the experiments reported upon in this article, as already mentioned, many unfertilized eggs failed to produce adults. Accordingly, it can not be stated without qualification (Phillips, 1915) that all unfertilized eggs are potential males. The Wagner theory that the size of the cell in which the egg is laid controlls the fertilization of the egg certainly can not apply in the case of bumblebees, for the egg cells are small structures and moreover no constant difference in cell width or size is discernible. Dickel's view that a fertilized queen honeybee can not lay unfertilized eggs will not coincide with the facts as they exist in bumblebees; namely, that fertilized queen bumblebees can lay eggs which produce males as well as females.

Another generally accepted hypothesis is that the queen can voluntarily control the issuance of sperm from the spermatheca and accordingly produce males or females. Though this seems to be the case in wasps and the honeybee, no real evidence was found to support such a contention in the case of the bumblebees. In the course of my studies all the first progeny of the queens were found to be females and the males were not produced until the colonies were approaching their "climax" development. In Experiment 11, 1917 (*B. bimaculatus*), it was quite evident that after the male eggs first began to be laid there was a gradual increase in the ratio of their number over those of the female eggs. In Experiment 6, 1919 (*B. impatiens*), after male eggs once began to be laid no more female eggs were laid—at least all eggs producing adults (a very large number) were males. Sladen has also studied colonies that produced all females. In view of the fact that differentiated cells for the reception of male or female eggs have not been found, and that males under normal conditions appear after the majority at least of the female eggs have been laid (in fact may never appear), a voluntary control of the sex of the eggs is an unnecessary explanation. It seems equally logical in the case of the bumblebees to assume that the male eggs begin to appear at that time in the life of the queen when the store of sperm in the spermatheca becomes diminished, they lose their effectiveness, etc. This would explain why the eggs laid first always produce females (with possible exceptions in the arctic regions where degree of fecundity is probably very low) and that males are usually produced late in the reproductive life of the queen.

Support of the data relating to the fact that queens and workers of the honeybee are produced by feeding is found in the case of bumblebees. Whether the quality of food exerts a controlloing influence upon the production of workers or queens (as is true of the honeybee) was not determined. The fact that the larval stage is much longer in large workers than in small workers and longest in the case of the queen of *Bremus* suggest that quantity alone may account for the differentiation in size. In many ways, the development of the various sized females of *Bremus* represents an intermediate degree of specialization between the honeybee and the more generalized condition found in the solitary bees.

In a paper by Lindhard (1912), a Danish biologist, there is presented the idea that eggs laid by workers must be of some use and that they are fed to larvæ destined to become queens. The basis of this view was that he once saw a queen destroy some worker eggs, one of which after being chewed was laid together with a little pollen on top of a cell of a queen larva. In my colonies where a very close watch was kept of the development of all eggs laid by the queens or workers, I failed to find any evidence to support such an explanation of the origin of the queens. As already mentioned, it is my opinion that the number of egg-laying workers in a normal nest is over-played. If a useful purpose must be attached to the fact that workers lay eggs, we may consider the production of males to fertilize the young queens a useful purpose. If the causes for the laying of male eggs by the queens are as stated elsewhere in this paper, then such a purpose is perhaps not always purely a case of wasted effort. Sladen (1912) has stated that he has had under observation a colony of *B. pratorum* (Linn.) which only produced females. The fact that queens will destroy worker eggs is quite true as will be recorded elsewhere, but these actions find their explanation by other behaviorisms. I do not think, therefore, that the development of queens is dependent upon malaxated eggs being fed to the larvæ, granting that such a type of cannibalism may occur.

Very few data are available concerning the development of *Psithyrus*. Though no females of *Psithyrus* have been homologized until recently (Plath, 1922) with workers (small females) of bumblebees, there is no reason why a miniature female *Psithyrus* is not the equivalent of a worker *Bremus*. Small females of *Psithyrus* do occur which are as small in proportion to their mother queen as are certain workers of *Bremus* to their mother queen. Plath (1922) figures a series of females of *Psithyrus* which illustrates such a range in size. These small females certainly indicate that they are due to trophogeny. In the field, small *Psithyrus* females are but infrequently encountered and I have never seen them flying around in spring. I have studied, however, pinned specimens of small females of *Psithyrus* which were captured in late spring. What we do know of the habits of *Psithyrus* all indicates that they have a development similar to that of bumblebees (Frison, 1926) and probably that which holds true for the sex determination of *Bremus* holds true to a large extent for *Psithyrus*.

Several facts warrant emphasis in briefly summarizing what has been stated concerning the development of the castes and sexes in bumblebees. The largest females, or queens, are capable of producing both males and females. All adults in my colonies reared from eggs laid by small unfertilized females or workers produced males. Workers are miniature queens, size being the only apparent external modification. A complete transitional series in size of females from the tiniest worker to the queen may exist within the same nest. Considerable evidence was obtained by the study of many colonies of several species of bumblebees that polymorphism of the females is due to trophogeny.

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EXPLANATION OF PLATES.

PLATE IX.

Fig. 1. Adults of *Bremus impatiens* showing variation in the size of females and males.

Fig. 2. Adults of *Bremus bimaculatus* showing variation in the size of females and males.

PLATE X.

Fig. 3. Adults of *Bremus vagans* showing variation in the size of females and males.

Fig. 4. Adults of *Bremus americanorum* showing variation in the size of females and males.

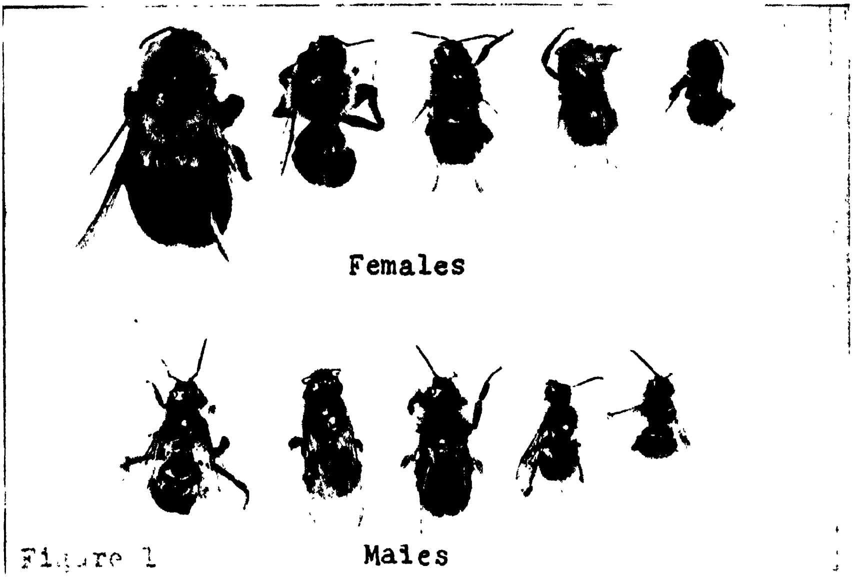

Figure 1

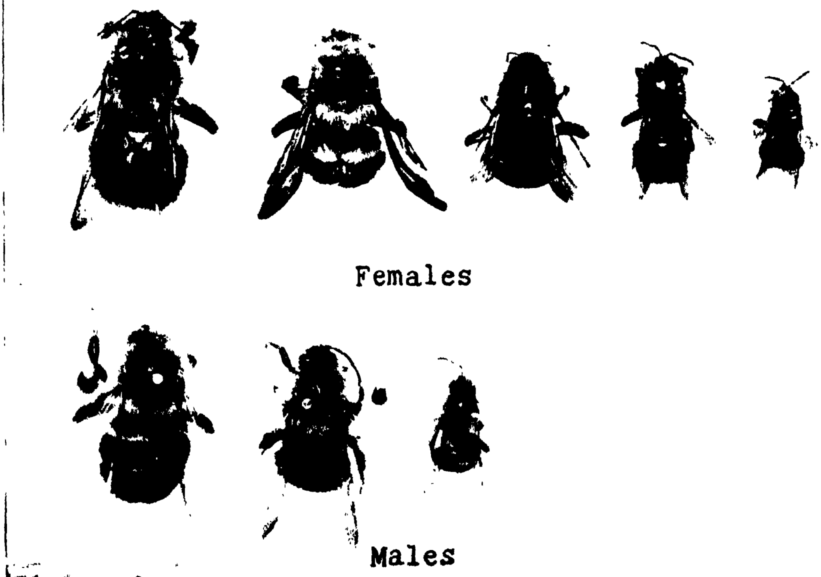

Figure 2

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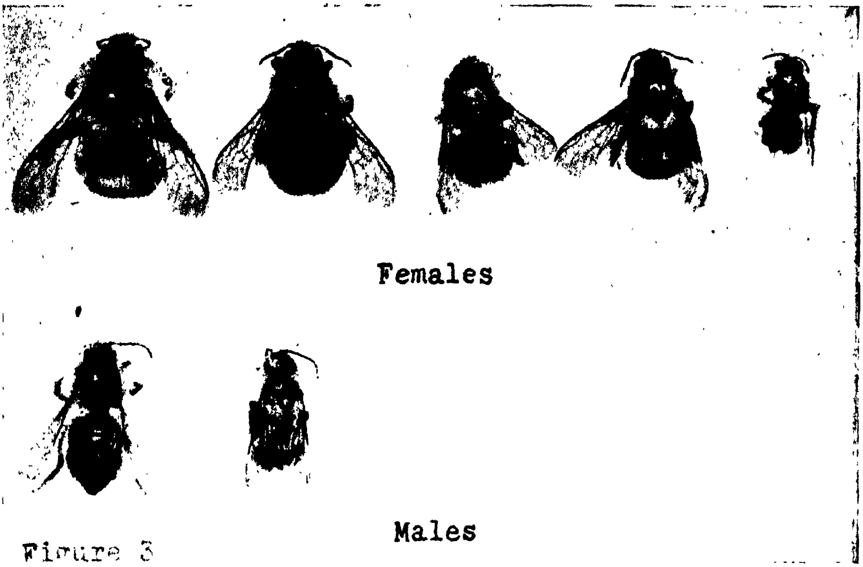

Figure 3

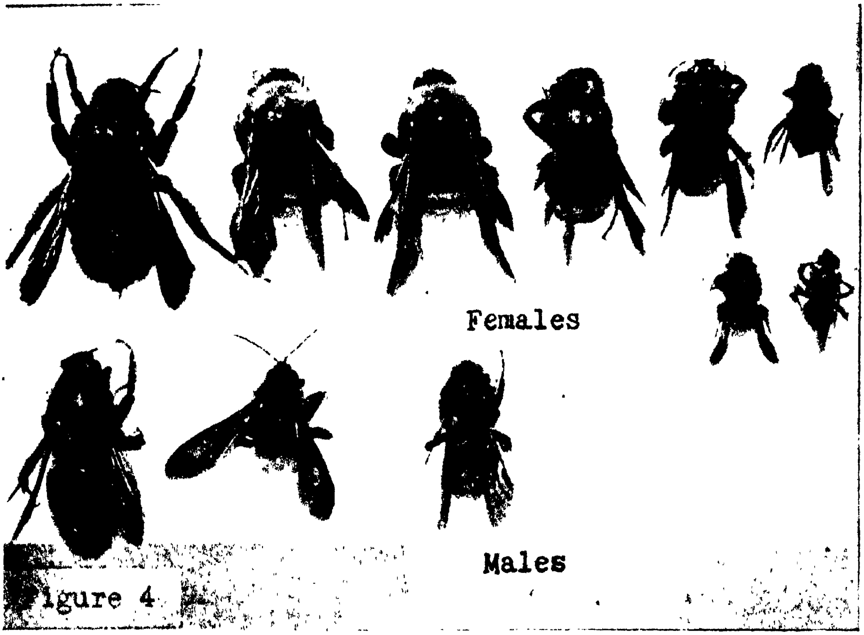

Figure 4

Theodore H. Frison

NOTES ON THE HIBERNATION OF SEVERAL NORTH AMERICAN BUMBLEBEES.*

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Although our knowledge concerning the life-history and habits of the various species of bumblebees which inhabit the arctic regions and the Tropics is rather meager, it seems to be definitely established that the colonies of at least some of the tropical species are perennial (cf. von Ihering, 1903), while those of arctic species probably last only a month or two (cf. Friese und von Wagner, 1912, and Frison; 1919). In fact it has been suggested by Sparre-Schneider (1909) that some of the arctic species, *e. g. Bremus hyperboreus* and *Bremus kirbyellus* are solitary in certain parts of the far north. This hypothesis, though interesting, still lacks confirmation.

In the Temperate Zone we have conditions which are more or less intermediate between these two extremes. In the milder parts of the Temperate Zone, such as Corsica, Sardinia, and New Zealand, bumblebees may be seen on the wing throughout the year,† but their colonies, although persisting during the greater part of the year, are probably not perennial. Similar conditions no doubt obtain in certain parts of the United States, *e. g.* the warmer regions of the South and the sheltered rim of the Pacific Coast. However, in the colder parts of the Temperate Zone, such as New England and Central Europe, we have conditions which more closely approximate those of the Arctic, the only difference being a somewhat longer period of activity during the summer. Here in the vicinity of Boston, this period of activity usually ranges from three to six months (about April 15 to October 15), depending on climatic conditions and upon the species. During the remaining six to nine months, the young queens—the only caste which survives our rigorous winters—go into hibernation. Sladen (1912), the foremost English authority on the biology of bumblebees, has the following to say concerning the manner in which the young queens of some of the European species spend this protracted period of inactivity.

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*Contributions from the Entomological Laboratory of the Bussey Institution, Harvard University. No. 281.

†Cf. Ferton (1901), Krausse (1910), Hopkins (1914), and Hudson (1918).

"Immediately after fertilisation the queen seeks a bed in which to take her long winter sleep. The queens of some of the species hibernate under the ground, others creep into moss, thatch, or heaps of rubbish. I have found *B. lapidarius* and *B. terrestris* and occasionally *B. ruderatus* and *B. latreillellus* in the ground, *B. lucorum* and *B. hortorum* in moss, and *B. pratorum* sometimes in the ground, sometimes in moss.

"My observations have been made chiefly on the underground-hibernating species, *lapidarius* and *terrestris.* Both species pass the winter in much the same situations, but *terrestris* likes best to burrow in ground under trees, while *lapidarius* prefers a more open position, almost invariably choosing the upper part of a bank or slope facing north or north-west, though generally near trees.

"In such banks I have sometimes found great numbers of queens, chiefly *lapidarius,* and it is easy to discover them, because in burrowing into the ground each queen throws up a little heap of fine earth, which remains to mark the spot until the rains of autum wash it away. The burrows are only one to three inches long, and if the bank is steep they run almost horizontally. They are filled with the loose earth that the queen has excavated. The queen occupies a spherical cavity having a diameter of about 1⅛ inch.

"It is evidently damp and not cold that the queens try to avoid. Indeed, the northern aspect shows that they prefer a cold situation, and the reason is easily guessed. The sun never shines on northern banks with sufficient strength to warm the ground, so that the queens do not run the risk of being awakened on a sunny day too early in spring, for the queen humble-bee is very susceptible to a rise in temperature in the spring, although heat in autumn, even should it amount to 80° F., will not rouse her when once she has become torpid. The queen easily takes fright while she is excavating her burrow, and I find that many burrows are begun and not finished.

"The queen always fills her honey-sac with honey before she retires to her hibernacle. This store of liquid food is no doubt essential for the preservation of life, and is especially needed, one would think, during September, when the ground is often very dry and warm . . . . . .

"I have dug up the hibernating queens of *Ps. rupestris, vestalis, barbutellus*, and *campestris* from banks facing northwest, occupying little cavities in the ground, about two inches below the surface, exactly like the queens of *B. lapidarius* and other *Bombi.*"

This account of Sladen (pp. 14-16, 72) agrees with that of Hoffer (1882–83, p. 8), except that the last-named author asserts that the young queens prefer a slope facing east for their *hibernaculum*, and that they spend the winter "deep in the bowels of the earth." As will be seen from the following observations, the statements of both of these authors will have to be somewhat modified.

Toward the end of the summer of 1922, some Italian workmen in the Arnold Arboretum showed me a hole in a level, grass-covered spot, where they had seen a number of bumblebees enter. However, it was impossible for me to investigate whether this was the entrance to a bumblebees' nest, until October 15. Unfortunately I lost track of the hole as soon as I began to work, and although I dug down several feet, I was unable to discover any nest, but was rewarded by finding 21 hibernating queens of *Bremus impatiens* in the sod about the hole. All of them were numb, but after being exposed to the comparatively mild air for a few minutes, several took wing.

Having read Sladen's (1912) account concerning the hibernation of *Bremus lapidarius*, I came to the conclusion that these 21 queens had chosen this particular spot in which to spend the winter, because they had found it especially suitable for this purpose. However, the following observations—made since that time—have convinced me that there are other reasons, than those suggested by Sladen (1912), why the young queens of certain species of *Bremus* are found hibernating near each other in large numbers.

On October 2, 1923, I made an unsuccessful attempt to dig up a colony of *Bremus impatiens* in a level, but rather sandy spot in the Arnold Aboretum. Besides several workers which were frantically searching for the entrance to their nest, I discovered 13 young queens of *Bremus impatiens* hibernating several inches below the surface, within a radius of about 2 ft.

This led me to suspect that the young queens of *Bremus impatiens* usually hibernate near the maternal nest, and that the hole about which I had found the 21 hibernating queens on October 15, 1922, was the entrance to a bumblebees' nest, as was asserted by the workmen who showed it to me. The following observations furnished further proof for this assumption.

On October 6, 1923, I dug up a colony of *Bremus impatiens* in a sandy slope facing south-west. About the entrance to this nest I found over 30 hibernating queens of this species, while the nest itself, in addition to the old queen and several workers and males, contained about a dozen more which had not yet gone into hibernation.

During the past summer I decided to learn more as to how the young queens of *Bremus impatiens* prepare their *hibernaculum*. An excellent opportunity for this investigation was furnished by an exceptionally large colony of *Bremus impatiens* which was discovered in the Arnold Aboretum in August 1926. In the early part of September, young queens could be seen entering and leaving the nest whenever the weather was pleasant. On September 25 and 26, more than 40 young queens were found busily at work digging their *hibernacula* in the sod,* surrounding the nest entrance. Scattered among the little heaps of fresh soil which these young queens were piling up were many others which had been deposited earlier. Near each one of these was a cavity, about ½ inch in diameter. Several of these cavities were examined, and in almost every one a young queen of *Bremus impatiens* was found at a depth of about 2 or 3 inches. The place was again visited on October 1 and 17. By this time most of the little piles of soil had been washed away by rain, and the openings to the *hibernacula* were closed, but on both of these visits several young queens were still busy digging themselves in. On November 11, the piles of soil had disappeared, and no openings could be seen. However, several spades of sod were turned over within a radius of about 4 ft. of the nest entrance, and each of these contained from 2 to 5 hibernating queens of *Bremus impatiens*. These were slowly, but angrily vibrating their wings and protruding their stings, near the tip of which could be seen a small droplet of venom.

Being interested to know at what depth, and in what state, I would find the queens in the middle of winter, I pried loose

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*Réaumur (1742) apparently made similar observations, probably on *Bremus lapidarius*, but he seems to have placed them in spring by mistake.

a piece of sod, about nine inches square, near the nest entrance, on February 5, 1927. On this day the minimum temperature was 10° F., and the ground was frozen to a depth of about six inches. The piece of sod was then broken up with a pick to see whether it contained any hibernating queens. Three queens of *Bremus impatiens* were obtained during this operation. Although I dug down about 2 ft., none were found hibernating in the soil below the frozen layer. Of the three queens, No. 1 had been completely crushed by the pick, No. 2 had lost a part of one hind leg, but No. 3 was not injured in any way. Although found imbedded in the frozen ground, these queens had maintained a sufficiently high body temperature to prevent them from freezing solid. Probably as a result of the accident to her leg, queen No. 2 was feebly moving when first noticed, while No. 3 appeared to be dead. During the ten minute walk home, I carried queens No. 2 and No. 3 in the hollow of my hand. When I entered my room, queen No. 3 began to show signs of life by slightly twitching her tarsi. After being exposed to a temperature of about 65° F. for a few minutes, both queens feebly vibrated their wings when disturbed, but did not show their stings. About half an hour later, they began to crawl about, but they refused to eat some honey which was offered to them on that, and on the following day. It is estimated that from two to three hundred queens of *Bremus impatiens* were hibernating in the frozen sod near the place where these three queens were found.

In this connection some observations of Hoffer (1882–83, p. 8) are of interest. About the middle of October 1881, this author dug up a once populous nest of *Bremus lapidarius*, but it contained only some moldy comb and five dead workers. However, in some chewed-up grass in a depression, about 2 ft. from the nest, he found a lethargic queen of *Bremus lapidarius** whose glossy pile indicated that it had been reared during the preceding summer. This author also states that

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*About a century ago, Huber (1802), on August 21, took a nest of *Bremus muscorum* in which he found only a few young queens, but he discovered about 35 additional queens in a small cavity, connected with the nest by a narrow passage. From this he concluded that these queens would have hibernated in the cavity, if he had not disturbed them. However, in view of the fact that young queens habitually retreat to such cavities, if available, whenever their nest is disturbed during the summer and fall, this assertion of Huber (pp. 81–82) need not be taken too seriously, especially when one considers that this nest was taken rather early in the season.

he found hibernating *lapidarius* queens "without a trace of grass" in some holes which they had dug themselves, presumably near this same nest, although his account does not make this entirely clear.

From the foregoing observations it is evident that the young queens of *Bremus impatiens,* and probably also those of its close Old World relative, *Bremus lapidarius*, under normal conditions, hibernate in the soil about the entrance to the maternal nest.

I have repeatedly dug in situations, such as Sladen (1912) describes, but only on one occasion have I found a hibernating queen (see below). This fact, and the observations of Hoffer (p. 8), lead me to believe that Sladen (p. 15), like myself in 1922, was unwittingly dealing with a former nesting site, when he found so many young queens of *Bremus lapidarius* hibernating in one place.

It must be pointed out, however, that the habit of the young queens of *Bremus impatiens* to hibernate in the soil about the maternal nest is not a fixed and unalterable instinct. During the past six summers I have transferred over 50 colonies of *Bremus impatiens* to nest-boxes (cf. Plath, 1922a) which were kept in several different situations. Some of these colonies were placed in a third story window of the Bussey Dormitory facing south, others in a window of the second story, facing north, while the remaining colonies were kept on two boards in an abandoned cellar, the boards being about 2 and 6 ft., respectively, from the cellar floor. The higher of the two boards, it may be added, was about on a level with the ground outside the cellar. The soil below the windows of the dormitory, as well as that surrounding the cellar, was covered with sod similar to that in which I have found large numbers of hibernating queens of *Bremus impatiens,* while that in the cellar was barren, and mixed with a considerable quantity of sand. Although hundreds of young queens of *Bremus impatiens*, as well as those of other species, were reared in both of these places, none were found hibernating in the soil nearby.

Having established the fact that, with conditions favorable, the young queens of *Bremus impatiens* hibernate in the soil about the entrance to the maternal nest, I was curious to know whether the young queens of some of our other New England species have the same habit. For this purpose a large colony of *Bremus affinis*, discovered during the first part of September 1925, was left undisturbed, since many young queens were observed entering and leaving this nest, the tunnel of which entered the ground among some old leaves in a wooded part of the Arnold Aboretum. On November 21, 1925, I dug about the nest entrance, but did not find a single queen. Similar investigations were made in connection with a large colony of *Bremus fervidus* which was discovered during the summer of 1926, the nest being situated in an open, grass-covered slope. On September 25, a number of young queens of *Bremus fervidus* were seen entering and leaving this nest. However, when the deserted nest was dug up on November 11, not a single queen was found hibernating in the sod about the nest, although in both this and the foregoing case, conditions seemed to be ideal for this purpose. While it is not advisable, as a rule, to base definite conclusions on negative evidence, the foregoing observations nevertheless suggest the probability that the young queens of *Bremus affinis* and *Bremus fervidus* do not, under normal conditions, hibernate near the maternal nest, as do those of *Bremus impatiens*.

Bremus affinis belongs to the same group of bumblebees as the European *Bremus terrestris*, and it is stated by Sladen (p. 14) that the young queens of the latter species "like best to burrow in the ground under trees" when seeking a place in which to hibernate. If this is true, it seems probable that the young queens of *Bremus affinis*, and those of other species belonging to the Terrestris group, hibernate in similar situations.

HIBERNATION OF CAPTIVE QUEENS.

The late F. W. L. Sladen (1912) seems to have been the first who attempted to overwinter captive queens. In the fall of 1910, and again in 1911, this author confined some young queens of *Bremus lapidarius*, but none of these experiments proved successful. Better results along this line were obtained by the Danish biologist Lindhard (1912). After failing in his first attempt, this author succeeded in overwintering a number of young *terrestris* and *lapidarius* queens. I should here like to discuss briefly two attempts to overwinter young queens of *Bremus impatiens*.

EXPERIMENT I.

Of the 21 hibernating queens of *Bremus impatiens*, dug up on October 15, 1922, 16 were placed in a box containing about 6 inches of soil. The queens refused to dig themselves in, probably because the conditions were not suitable, and by December 26, all but 4 had died. When disturbed, these 4 queens, numb from cold, began to vibrate their wings very slowly, and although no longer molested, continued to do so for several minutes, as if unable to stop. None of these queens survived the winter.

EXPERIMENT II.

About 30 young queens of *Bremus impatiens* which were found hibernating about the nest taken October 6, 1923, were confined in wire cages from which the bottoms had been removed. These cages were then placed on the north side of a fence, and were lowered about a foot below the surface of the ground to prevent the queens from escaping. By October 14, all the queens had dug themselves in, but apparently only three survived the winter, the first one appearing May 14, 1924, and the other two on May 15.

As stated in the introduction, bumblebees here in the vicinity of Boston are active from about April 15 to October 15. In the following paragraphs I shall briefly record the time, and approximate length, of hibernation of the New England species which occur in this part of Massachusetts, these data being based chiefly upon observations which I have made in the neighborhood of Boston during the past five years. I have also included some valuable notes by Professor O. A. Stevens, of North Dakota Agricultural College, and Mr. F. H. Walker of Salem, Mass.

A. GENUS BREMUS.

Terrestris Group.

I. *Bremus affinis* Cresson (Including its var. *novae-angliae* Bequaert).

Here in the vicinity of Boston the queens of *Bremus affinis* usually begin to leave their winter quarters about the middle of April, but in the exceptionally early spring of 1925, a queen of this species was seen as early as April 7. Mr Walker's earliest record is April 19. In May, the queens are exceedingly abundant, especially on Rhododendron. The young queens are produced chiefly in August and September, the period of hibernation therefore covering about 7 months.

II. *Bremus terricola* Kirby.

Although far less common than the preceding species after about May 1, the queens of *Bremus terricola* are usually more abundant in April. This indicates that the queens of *Bremus terricola* leave their winter quarters somewhat earlier than those of *Bremus affinis.* My earliest record for *Bremus terricola* is April 6, 1925 (on Rhododendron). Most of the young queens are produced during July and August, and hence the period of hibernation is probably somewhat longer than that of *Bremus affinis.*

Borealis Group.

I. *Bremus borealis* Kirby.

Since *Bremus borealis* is extremely rare in this part of New England, it is rather difficult to make any definite statements concerning the habits of this species. I have seen only four living specimens, all of which were queens. The dates are as follows: No. 1, May 29, 1922 (on Diervilla); No. 2, June 6, 1922 (on Rhododendron); No. 3, July 8, 1922 (cf. Plath, 1922b); and No. 4, June 10, 1925 (on Cladrastis and Robinia). The last two queens were heavily laden with pollen, and hence had probably started colonies. These data suggest that the queens of *Bremus borealis*, like those of its close European relative, *Bremus distinguendus* (cf. Hoffer, 1882–83, p. 72) appear rather late in spring. Since in all late-appearing species, the sexual forms are apparently not produced until August and September, it is probable that *Bremus borealis* is no exception to this rule.

Pratorum Group.

I. *Bremus bimaculatus* Cresson.

The queens of this species begin to appear about the same time as those of *Bremus terricola*, *i. e.* about the middle of April, my first record being April 7, 1925 (on Rhododendron). Like *Bremus pratorum* in Europe, *Bremus bimaculatus* completes its life-cycle very early, most of the young queens being produced in June and July.

While digging up a colony of *Bremus terricola* in a sandy and densely wooded slope facing north, on July 7, 1925, I accidently found a young queen of *Bremus bimaculatus* hibernating in the cool sand, about 6 inches below the surface. Although quite drowsy at first, this queen soon became active and flew away. The young queens of *Bremus bimaculatus* therefore hibernate about 9 months.

II. *Bremus impatiens* Cresson.

Although a queen of this species was seen as early as April 12, 1925 (on Pieris and Erica), the majority do not appear until several weeks later, Mr. Walker's earliest record being May 1. Most of the young queens are produced during August and September, the period of hibernation lasting about 8 months.

III. *Bremus perplexus* Cresson.

My earliest spring record for this comparatively rare New England species is April 12, 1925 (on Rhododendron). As in the case of *Bremus bimaculatus*, the colonies of *Bremus perplexus* apparently break up rather early (cf. Plath, 1927), the young queens hatching chiefly in June and July.

IV. *Bremus ternarius* Say.

Until the spring of 1924, this beautiful species was exceedingly rare in the vicinity of Boston (cf. Plath, 1927). In an earlier paper it was stated that the queens of *Bremus ternarius* "seem to leave their winter quarters comparatively late in spring" (cf. Plath, 1923). In a letter, dated March 24, 1923, Professor O. A. Stevens makes the following comment on the above statement: "*B. terricola* is one of our common species, and one of the earliest to appear, as you note. With it, or slightly before, comes *B. ternarius.*" Subsequent observations have proved the correctness of Professor Stevens' remarks. On April 5, 1925, Dr. Joseph Bequaert and myself saw a queen of *Bremus ternarius* (on willow), this being my earliest record for any of our New England species. Two days later, four additional queens were seen on the flowers of a Pieris bush. Judging from a large colony taken at Petersham, Mass. on September 15, 1923, most of the young queens are probably produced in August and September. The period of hibernation therefore extends over about 7 months.

V. *Bremus vagans* Smith.

Of the five New England species belonging to the Pratorum group, this is the latest to appear, Mr. Walker's earliest record being April 29, and my own, May 6. The young queens are produced chiefly in August and September, the period of hibernation amounting to about 8 months.

Auricomus Group.

I. *Bremus auricomus* Robertson.

This is one of the New England species which I have been unable to discover in the vicinity of Boston.

Fraternus Group.

I. *Bremus rufocinctus* Cresson.

Like the foregoing, this rare New England species does not seem to occur in this part of Massachusetts.

II. *Bremus separatus* Cresson.

This is one of our less common New England species. My first records are May 13, 1923, and May 13, 1924, both on *Ribes aureum.* Most of the young queens are probably produced in August. In a nest taken on June 23, 1924, and transferred to the Bussey Institution, the first queen hatched as early as July 22, (cf. Plath, 1927). As in the case of *Bremus bimaculatus*, the young queens of *Bremus separatus* therefore hibernate for about 9 months.

Dumoucheli Group.

I. *Bremus americanorum* Fabricius.

In this part of New England, *Bremus americanorum* is even less common than the preceding species, and the queens are among the last to appear in spring, my first record being May 27, 1923. Judging from a colony which I had under observation in that year, the young queens are reared chiefly in August and September, the period of hibernation being about 8 months.

II. *Bremus fervidus* Fabricius.

As in the case of *Bremus americanorum*, the queens of *Bremus fervidus* appear rather late, my first record being May 6, 1923, and that of Mr. Walker, May 26. The young queens are produced largely in August and September. Hibernation therefore extends over a period of about 8 months.

B. GENUS PSITHYRUS.

Ashtoni Group.

I. *Psithyrus ashtoni* Cresson.

The females of this species appear about a month later than those of its hosts, *Bremus affinis* and *Bremus terricola*, my first record being May 6, 1924, and Mr. Walker's, May 21. The young females are produced chiefly in August, but I also have a few records for July and September. The period of hibernation is, therefore, about 9 months.

Fernaldae Group.

I. *Psithyrus fernaldae* (=*tricolor*) Franklin.

Although *Psithyrus fernaldae* is not rare in certain parts of New England (cf. Bequaert and Plath, 1925), I have never taken a specimen in the neighborhood of Boston. The host of *Psithyrus fernaldae* is not known.

Laboriosus Group.

I. *Psithyrus insularis* (=*consultus* Franklin) Smith.

I have never encountered this species, which, according to Franklin (1912), is extremely rare in the eastern part of the United States.

The host of this *Psithyrus*, or at least one of them, is *Bremus flavifrons* Cresson (cf. Sladen, 1915).

II. *Psithyrus laboriosus* Fabricius (Including its variety *citrinus* Smith).

In the vicinity of Boston, this is by far the most common Psithyrus. As in the case of *Psithyrus ashtoni*, the females of *Psithyrus laboriosus* appear about a month later than the queens of their hosts, *Bremus impatiens and Bremus vagans*. Mr. Walker's earliest record for *Psithyrus laboriosus* is May 21, and my own, May 28 (on Vaccinium). The young females, like the young queens of their two hosts, are produced chiefly in August and September. The period of hibernation therefore lasts about 9 months.

SUMMARY AND CONCLUSIONS.

1. The young queens of *Bremus impatiens*, and probably also those of *Bremus lapidarius*, under normal conditions, hibernate in the soil about the entrance to the maternal nest.

2. As in the case of some of the European species, it is possible to overwinter captive queens of *Bremus impatiens*.

3. *Bremus terricola* and *Bremus affinis*, our New England representatives of the *Terrestris Group*, leave their winter quarters rather early in spring, as do their Old World relatives, *Bremus lucorum* and *Bremus terrestris*.

4. *Bremus borealis* apparently appears rather late in spring, as does its close European relative, *Bremus distinguendus*.

5. *Bremus bimaculatus*, like *Bremus pratorum* in Europe, appears early in spring, and like the latter, completes its life-cycle early in the summer.

6. As in the case of the European Psithyri whose habits have been studied, the females of *Psithyrus ashtoni* and *Psithyrus laboriosus* leave their *hibernacula* about a month later than the queens of their hosts.

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THE IMMATURE STAGES AND LARVAL ANATOMY OF ANOMALA KANSANA H. AND McC. (SCARABÆIDÆ, COLEOP.).*

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INTRODUCTION.

During the course of a series of life-history studies of the Scarabæidæ at the Kansas Agricultural Experiment Station, Manhattan, Kansas, an opportunity was presented to assemble a fairly representative series of reared specimens of the immature stages of the common representatives of that family of insects occurring in the region. These have been accumulated with the intention of presenting, sometime in the future, a detailed morphological study which may aid in elucidating characters sufficiently reliable to enable the various larvæ to be recognized without resorting to rearing. Considerable progress along that line has been made which ultimately may produce the results desired.

Among the various species whose life-history was worked out† was a species of Anomala pronounced by specialists as new and described by Hayes and McColloch‡ as *Anomala kansana* (Fig. 30). The immature stages of any insects are always of interest and in the past have been too frequently neglected by entomologists. Moreover, the close affinity of *A. kansana,* with the recently introduced oriental species of the same genus, *Anomala orientalis* W., which occurs in New England, and its not far distant relationship with the Green Japanese Beetle, *Popillia japonica* Newm. make it apparent that such a study as presented herein may be of some value in connection with these important immigrants. On the other hand several native species of Anomala, namely, *binotata, flavipennis* and *innuba* cause serious damage at times to such crops as fruit and grains.

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*Contribution No. 113 from the Entomological Laboratories of the University of Illinois.

†Hayes, Wm. P. and McColloch, J. W., The Biology of *Anomala kansana* (Scarabæidæ, Coleop.). *In* Journ. Econ. Ent. Vol. 17, pp. 589–594, 1925.

‡Hayes, Wm. P., and McColloch, J. W., A New Species of Anomala. *In* Ent. News. Vol. 35, pp. 138–140, 1924.

In his study of the larval anatomy of the Green Japanese beetle, *Popillia japonica*, Böving* made a comparative study of the anatomical features of the Popillia larva with that of an undetermined species which he supposed to be *Strigoderma arboricola* Fab. He gives a translation of Schiödte's† characters of scarabæid larvæ and constructs a key to related genera of Popillia. In this key the genus Anomala is separated from Popillia and Strigoderma (?) on the fact that the claws of the last pair of legs in Anomala are abruptly shorter than those of the fore and middle legs, while in the other genera they are equal in length. Use is also made of the minute anatomical arrangement of the surface of the spiracular peritreme or bulla. This character is of doubtful value for a key because of the difficulty of distinguishing the shape of the so-called "holes."

Except for the work of Böving the writer is unaware of any detailed morphological study of any species of North American white grubs. The present anatomical details are based on a study of nearly mature or third instar (Fig. 1) larvæ. The second instar shows little marked differences, except size, from the third instar while the first instar larvæ differ somewhat in the development of the setal pattern, especially on the ventral aspect of the tenth abdominal segment.

THE EGG STAGE.

The egg (Fig. 26) is laid in the soil and as with other scarabæid eggs it increases in size and differs in shape as embryological development proceeds. At first the egg is elongate oval in form. It gradually changes to a more spherical shape as it gets older. The color varies from a milky-white to a pearly-gray. When freshly laid the eggs are about one millemeter wide and 2.25 millemeters long. One gravid female upon dissection was found to contain 26 full sized eggs and the total number laid probably greatly exceeds this number. During the course of the life-history study of this species it was not observed whether or not the eggs are enclosed by a capsule of surrounding soil which is held together by a secretion of the female as is the case with other species of the family. It no doubt occurs nevertheless.

Egg-laying was observed in 1921 to begin on June 15, in 1922 on June 14 and in 1923 on June 26. The length of the egg stage varied from 9 to 19 days with markedly different averages for the four seasons

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*Böving, A. G., The Larva of *Popillia japonica* Newman, and a Closely Related Undetermined Ruteline Larva. A Systematic and Morphological Study. *In* Proc. Ent. Soc. Wash., Vol. 23, pp. 51–62, 2 pl. 1921.

†Schiödte, J. C. De metamorphosi Eleutheratorum observations. *In* Naturhist. Tidsskrift, series 3, vol. 9, pp. 227–236, pl. VIII–XIX. 1874.

observed. In 1920 the range of the egg stage for 5 eggs observed was from 13 to 15 days with an average of 14.6 days. In 1921 for 486 eggs the range was from 9 to 19 days with an average of 12.6 days. In 1922 for 40 eggs the range was from 9 to 16 days with an average of 13.9 days and in 1923 for 101 eggs from 9 to 17 days with an average of 11.9 days. A summary of the above figures shows a total of 632 eggs under observation with greatest extremes of 9 and 19 days and an average for the 632 eggs of 12.2 days.

THE LARVAL STAGE.

The larvæ of *Anomala kansana* closely resemble the larvæ of other species of the genus and possess much in common with other grubs of the family Scarabæidæ. Upon hatching the first instar larvæ (Fig. 27) are about four millemeters long or about twice the length of the egg. The head is about 1.25 mm. wide and the thorax 1.5 mm. wide. When ready to moult to the second instar, the first instar larvæ have increased in length to 13 mm., the head is 1.5 mm. wide, only a slight increase in width, and the thorax is 2.5 mm. wide. The second instar (Fig. 28) individuals vary in size. Soon after moulting they are about 13 mm. long. The head is 2.5 mm. wide and the thorax 3 mm. wide. The last or third instar grubs when nearly mature vary from 20 to 24 mm. in length. The head is 3.75 mm. wide and the thorax at its greatest width is approximately 6 mm. wide. The head is tan colored and the body creamy-white in color.

The total length of the larval stage, including the prepupal stage was noted for 23 individuals and found to average 336.3 days with a minimum of 322 days and a maximum period of 345 days. The first molt occurred from 12 to 36 days after hatching while the second molt varied from four to 53 days after the first molt. The following table (Table I) taken from the work of Hayes and McColloch (loc. cit.) summarizes the length of the various periods of the larval stage.

TABLE I.

The Length of the Larval Stage of *Anomala kansana*.

Period	Number of Individuals	Maximum Days	Minimum Days	Average Days
Hatching to first molt......	69	36	12	20.5
First molt to second........	46	53	4	16.8
Second molt to prepupa.....	20	308	280	298.3
Second molt to pupa........	21	311	285	301.6
Prepupa to pupa...........	105	16	2	4.06
Total larval stage..........	23	345	322	336.3

ANATOMY OF THIRD INSTAR LARVA.

HEAD.

Cephalic Aspect: The cephalic aspect of the head (Fig. 6) capsule, if the clypeus and labrum is excluded, is nearly hemispherical in outline, light tan in color, and is divided by the inverted Y-shaped ***epicranial suture*** (es) into three regions. The stem of the Y has, about mid-way between the branches and the occiput, a widened, slit-like invagination caused by an infolding of the head capsule forming a lamella for the attachment of muscles. Schiödte describes the epicranial suture as having raised margins in *Euchlora frischii* (Anomala) but it is not so in this species. The area on each side of the stem and branches of the epicranial suture is the divided ***vertex*** (v) (***parietials*** of Crampton), while the area enclosed by the arms is the *frons* or *front* (f). The surface of the vertex is comparatively smooth and bears a few scattered setæ which become more numerous and somewhat longer on the ventro-lateral angles. The five-segmented ***antennæ*** (ant. and Fig. 8) arise from a bulb-like protuberance of the ventro-lateral angles of the head capsule. The first antennal segment is about as broad as it is long, the second is about twice as long as broad, while the third is greatly elongated being nearly three times as long as the second. The fourth segment is about one-half the length of the third and slightly longer than the fifth which is more ovate and tapering to a point on its distal end. The fourth segment has a small sensory pit near its point of attachment to the fifth segment while the fifth has at least two well marked sense pits (Fig. 8. sp). Immediately below the point of attachment of the antenna and between the bases of the mandibles is a narrowly, triangular membranous area (mn) probably homologous with the ***mandibularia*** (basimandibula, trochantin of the mandible). A ***precoila*** (pcl) for the articulation of the mandible is located at the cephalic angle of the membranous mandibularia. It is in the form of a prominent condyle. Near the precoila is a darkened and somewhat invaginated area, the ***pretentorina***. This is the external mark of the prententorium (anterior arms of the tentorium). Between the two pretentorina is a transverse suture connecting the two points. This is the ***fronto-clypeal suture*** (fcs) which separates the area of the front from the clypeus which is quadrilateral in shape and strongly transverse. The ***clypeus*** is composed of two transverse divisions, the ***preclypeus*** (pc) which is somewhat membranous in character and the ***postclypeus*** (psc) which is more strongly chitinized. Their division is indicated in figure 6 by the dotted line. Attached to the ventral margin of the preclypeus is the ***labrum***, (l) which is strongly asymmetrical, and because of its rugose surface the ventral margin appears somewhat strongly crenate. A distal aspect of the labrum showing the setæ and rugose surface is shown in figure 23.

The lateral aspect of the head: The right lateral aspect of the head capsule with the mouthparts removed is shown in figure 5. The *front* (f) is apparent in this view and behind it the ***vertex*** (v) and ***gena*** (g) are seen to be fused. No eyes are present and beneath the base of the antenna (ant) which is partially removed, is the membranous articulation of the mandible. Behind or caudad of the vertex and gena is a narrowly triangular area which is divided into a dorsal and ventral region by a transverse *occipito-postgenal suture* (opg). The dorsal, narrowly triangular area is the *occiput* (oc) while the ventral, subquadrangular region is the *postgena* (pg). Immediately behind the postgena and occiput is an area (mla) comparable to the *maxillaria* or *maxillary pleurite,* which folds over the caudal region of the head and generally obscures the occiput and upper part of the postgena. The *clypeus* with its two divisions, the *preclypeus* (pc) and the *postclypeus* (psc) also appear in this aspect as does also the *labrum* (l).

THE MOUTHPARTS.

The mouthparts are shown in relation to each other in figure 7. Since the head is of the hypognathus type the labrum which has already been described lies cephalad of the mandibles. This view shows the maxillary scraper (ms) consisting of a series of six curved teeth which lie in opposition to the file-like stridulating apparatus of the mandible. Neither the labium nor the labial palpus are seen in this aspect because of their being obscured by the maxillæ.

The Epipharynx: The *epipharynx* (Fig. 13), consisting, as in many other insects, of a group of strong setæ, is located on the caudal or inner aspect of the labrum. As pointed out the labrum is asymmetrical and at its distal end is an irregular emargination slightly to one side of the meson. Directly behind this notch on the inner surface is a small raised protuberance which bears four rather strong spines in addition to smaller setæ. Behind these spines the setæ are arranged in a somewhat irregular oval with a smooth area bearing no setæ within the oval. The setæ of the oval are directed toward the mesal plane. On the inner aspect of the *clypeo-labral* suture are two strongly chitinized tormæ (t). One on the right side is very regular and extends almost to the meson. Immediately behind the mesal point of this torma are some rather blunt spine-like chitinous projections which probably are a part of the epipharynx. The torma on the left is more curved and extends mesocephalad not quite reaching the mesal plane.

The ental surface of the clypeus, does not enter much into the makeup of the epipharynx having only a few setæ near its cephalic margin. In certain preparations the caudal margin of the clypeus can be seen to be elongated into two processes which continue ventrad to join the hypopharynx, (hc).

The Mandibles: The two *mandibles* (Figs. 11, 12, 14, 15) are unlike in shape and of a black and tan color. From the cephalic aspect the left mandible (Fig. 11) is seen to be stouter than the right mandible (Fig. 12). They each consist of a grinding or *molar* area (mo) and a cutting or *scissorial area* (sc) which bears, near the distal end, a small notch producing a slight *dentes* (dt). The molar area of the left mandible is somewhat subquadrate while that of the right is slightly concave with a rim of grinding teeth. Behind the molar area is a thinly chitinous setaceous area the *acia* (ac). These appear to arise on the ventral aspect from where it can be observed that the right acia is long and pointed while the left one is shorter and more rounded. On the dorsal aspect can be seen the *acetabulum* or *preartis* (pa) by which the mandible articulates with the condyle or precoila at the ends of the fronto-clypeal suture. An enlarged sketch of this articulation is shown in figure 17, in which the preartis is seen to articulate with a condylar *precoila* (pcl). The lateral aspect of each mandible presents a flattened surface or *scrobe* (sc) bearing a few setæ. Dotted lines in the drawing of the mandibles mark the areas of pigmentation.

The caudal aspects of the mandibles (Figs. 14 and 15) present the notched aspect of the *scissorial area* (sc) in much the same manner as the cephalic aspect but possess in addition a transversely, *striated area* (sa) arranged in the form of an oval. This is part of a so-called stridulating apparatus which occurs in a number of scarabæid larva and has been described by Schiödte (loc. cit.) and others. Opposed to this series of transverse striations on the maxillæ is a variable number of stridulating teeth (Fig. 21, 24, and 25, st) which will be described in connection with the maxillæ.

On the caudal aspect of the molar area can be noted the *acia* (ac) described above and in addition on the right mandible (Fig. 14) is a some-what rounded, lobe-like structure (x) which is apparently absent on the opposite mandible and which overlaps the hypopharynx when the mandible is closed. This lobe plays an important role in the grinding of food which will be mentioned later in connection with the hypopharynx. This aspect presents a condylar artis, the *postartis* (pta) on each mandible which articulates as seen in figure 7 with an acetabular *postcoila* (ptc) located on the gena. Attached to each mandible but only shown in two sketches (Figs. 11 and 15) are two chitinous processes for the attachment of muscles which have been described as tendons. The mesal tendon has been termed the *rectotendon* (rt) and the lateral one the *extensotendon* (et).

The Maxillæ: The maxillæ (Figs. 20 and 21) present the usual number of parts found in a chewing type of mouthparts except that the galea and lacinia are fused to form the single structure known as the *mala* (m). The *cardo* (cd) articulates with the postgena (Fig. 18) by an articular acetabulum, the *parartis* (pra) which fits into the *paracoila* (prc) located on the postgena. There are two divisions of the cardo into a *subcardo* (sc) which bears the articulation and the *alacardo* (ac) lying between the subcardo and the stipes. The *stipes* (s) is quadrilateral in outline on the caudal aspect, except at its distal end where it is fused to the mala, while on the cephalic aspect it is not separated from the mala. The *palpifer* (pf) is borne on the dorsolateral margin of the stipes. On the mesal margin is a narrowly, elongate sclerite the *parastipes* (ps) or subgalea of many authors. A membrane termed by MacGillivray the *labacoria* (lc) is attached to the inner margin of the cardo, parastipes and stipes. This membrane attaches to the labium and helps close the oral aperture. The *mala* (m) is densely setaceous and distally bears a series of strong spines. In many larvæ of the copraphagous Scarabæidæ the lacinia and galea are separately distinct and show no traces of fusion. The series of curved teeth-like structures found on the cephalic aspect are six in number on the right maxilla (Fig. 25) while only one was found on the left maxilla (Fig. 24). These teeth point and curve toward the distal extremity of the stipes and lie in apposition to the oval file-like area on the mandible (See Figs. 14 and 15). These stridulation structures, if such they be, have been described by Schiödte* who asserts that the teeth of the maxillæ differ in number and form according to the genera, and further noting that they vary in number from five to twenty, sometimes being straight but more often they are extremely sharp and curved. The ***maxillary palpi*** (mp) are four-segmented. The basal segment is about equal in length to the palpifer and about one-half the length of the second segment. The third segment is about one-half the length of the second while the distal segment is about twice the length of the third.

The Labium: The ***labium*** (Fig. 22) is small and usually concealed. It is partly covered on its lateral margins by the maxillæ. The ***submentum*** (sm) is large and somewhat quadrate. It is bordered laterally by the maxillæ (mx). A small, narrow, transverse area represents the ***mentum*** (mt) which is sharply differentiated from a wider transverse, ***stipula*** (st). Laterally the stipula is prolonged into a deflexed, broadened lobe which is covered by the maxilla. The fused ***glossæ*** and ***paraglossæ*** (lg) or ***ligula*** of some writers is broadly rounded on its distal margin. It is strongly setose and bears a pair of small. two-segmented labial palpi (lp).

The Hypopharynx: The ***hypopharynx*** consists of a densely, setaceous area on the ental aspect of the fused glossæ and paraglosæ and a strongly chitinized area (Fig. 16 and 19) termed by Böving (loc. cit) the hypopharyngeal chitinization (hc). The hypopharnyngeal chitinization is decidedly assymmetrical and somewhat less densely chitinized on the lateral extremities where it is irregularly inflexed to fit snugly against the molar region of the mandibles (Fig. 19) and it is the opinion of the writer that it serves as an accessory organ of mastication. The caudal margin of the chitinized area is continuous with the pharynx, which is probably held open by red-like structures extending dorsally to the epipharynx. In one preparation it was noticed that there is a direct connection between the ental aspect of the clypeus and the hypopharynx. These connecting bands of what appear to be slightly chitinized membranes are shown in figure 13, extending between the clypeus (cl) and the hypopharynx (hc). On the dorsal aspect, near the lateral angles, is a series of small setæ which are similar to the structures described by Carpenter† as the maxillulæ which Crampton asserts are homologous to the crustacean paragnatha.

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*Schiödte, G. C. Note sur les organes de stridulation chez les larves des Coleopteres lamellicornes. Ann. Soc. Ent., France. 5th Series. Vol. 4, pp. 39–41. 1874.

†Carpenter, G. H. Mouthparts of some Beetle Larva—. *In* Quarterly Journ. Micro. Soc. Vol. 57, pp. 373–376, 1912.

THE THORAX AND ABDOMEN.

The Thorax: The *thorax* (Fig. 1) consists of the usual three segments each of which bears a pair of jointed legs. The *prothorax* (I) is divided dorsally into three annulets, two of which are much wider than the small posterior one. The division of the two cephalic annulets does not extend far onto the pleuron. A small area of the cervix lying anterior to the three is sometimes apparent, depending on the degree of extension of retraction of the head which causes this segment to appear to be broken up into four annulets. The ventro-lateral angle of the propleuron extends cephalad to partially cover the head-capsule. Near its caudolateral angle is the prothoracic spiracle (Fig. 3) surrounded by a well-defined *peritreme* (p) which is open on its caudal margin in contradistinction to the peritremes on the other segments which are open anteriorly. The peritreme enclose an area known as the *bulla* (b). The prothoracic spiracle is nearly twice as large as the others. No other spiracles are present on the thorax. The prothoracic legs (Fig. 9) are shorter than the others. The *mesothorax* (II) on the dorsum exhibits three larger and more distinct annulets than those of the prothorax. The *metathorax* (III) likewise shows three ring-like divisions dorsally while the following or first abdominal segment shows but two. The metathoracic leg (Fig. 10) is considerably longer than the prothoracic. The elongation occurs in the *femur* (f). The distal end of each leg is provided with a single claw (Fig. 4), and two large setæ. The claws of the metathoracic leg are shorter than those of the other two pairs of legs. Following the interpretation of the parts of the leg (Figs. 9 and 10) as given by Böving (loc. cit.) in his description of the Japanese Beetle we find a long cylindrical *coxa* (cx) followed by a short *trochanter* (tr). The *femur* (fm) is long and slightly clavate while the next segment (tb) is interpreted as the *tibia* with the tarsus either absent or what is more probable, fused with the tibia since this structure bears the *tarsal claw* (cl and Fig. 4).

The Abdomen: There are eight pairs of spiracles on the abdomen (Fig. 1) on each of the first eight segments. The divisions of the segments are difficult to distinguish because of the annulets and these sometimes are obscured dorsally. From the present study it appears that the first abdominal segment shows but two annulets on the dorsal aspect while segments two to six, inclusive, show three each, segment seven has two while segments eight, nine and ten have but one each. The last or tenth abdominal segment is larger than the others and the anal slit is transverse. The terga and sterna of the abdominal segments are well marked but the pleura are ill-defined.

The Radula: The tenth segment on its dorsal aspect bears roughly three rows of short, stiff, straight setæ. Above these is a much denser cluster of longer setæ which become more numerous on the lateral margins. Ventrad of the anal slit is a group of setæ which occur in two sizes. The longer setæ are roughly arranged in transverse rows and are hooked at the tip. The shorter setæ are arranged in two rows extending cephalo-caudad along the meson and consist of very short recumbent setæ which point mesad. In some specimens there are ten such setæ in the row on the dextral side of the meson and twelve in the sinstral row (Fig. 2). On the dextral row the setæ are rather uniformly placed while in the sinstral row the spacing is not so uniform. This group of setæ is frequently figured by workers with white grubs. It has no name and as far as is known no function has been suggested for it. In a study of the digging habits of white grubs in observation cages the writer has frequently noticed the grubs making use of this structure to rake off the mouthparts which often become covered with soil as the larva burrows through the soil, especially if it is very wet and sticky. Since the general term "ventral aspect of the last abdominal segment" is cumbersome it is preferable to speak of it as the *rake* or *radula*. The radula does not differ strikingly in the second or third instars but in the first instar is not well developed and some of the spines and setæ are wanting.

THE PUPAL STAGE.

The pupa (Fig. 29) when freshly transformed from the larval stage is creamy white in color. As development proceeds, the darker colors of the adult insect are assumed. The greatest length is about 14 mm. and the greatest width across the thorax and wingpads is about 7 mm. It is not strikingly different from other Scarabæidæ pupæ but does lack the long, pointed, anal processes which occur in Phyllophaga pupæ. On the ventral aspect, the *front* (f) is seen to be a large semioval structure lying between the *compound eyes* (ce). Immediately behind the front is a somewhat quadrate *clypeus* (cl) with only a faint indication of a transverse division into a preclypeus and postclypeus as found in the larva. The *labrum* (lb) is caudad of the clypeus and is strongly rounded on its distal margin. Beneath the lateral margins of the labrum can be seen a part of the *mandibles* (md) and distad of the mandibles are two segments of the *maxillary palpi* (mp). On the mesal margin of the maxillary palpi can be seen the tips of the *maxilæ* (mx) and between these lying on the mesal line is the *labium* (la).

The tergum of the *prothorax* (pt) is noticeable on the ventral aspect lying on each side of the head. Adjoining the lateral margin of the prothorax and extending ventromesad is the *mesothoracic wing* (fw) under which lies the *metathoracic wing* (hw) only the tips of which are discernible at the distal end of the *mesothoracic* wings. Two pairs of legs, the prothoracic (pl) and the mesothoracic (ml) lie mesad of the wings and between these lie the *thoracic sterna* (st). The *metathoracic leg* (mtl) lies under the wings and only the tip of the tibia (tb) and the five segments of the *tarsus* (ts) are exposed beyond the distal end of the wings. Seven distinct abdominal segments (1-7) are evident. The seventh is strongly emarginate on its caudal margin and the developing *genitalia* (gt) appear as an oval process lying within the emargination. The pygidial end lying distad of the genitalia and seventh ventral segment bears the *anal slit* (al) and is slightly incised on its caudal margin to form two rounded lobes.

Pupation occurs in May, June and early July and varies in length from eight to 20 days. In all, 212 pupæ were observed for the length of the pupal stage. Among the grubs reared from the eggs, the pupal stage averaged 10 days for 16 pupæ. Grubs collected in the field, averaged 12.5 days in 1922 for 153 pupæ observed and in 1923, 44 pupæ had an average period of 9.9 days. These data are summarized in Table II taken from the work of Hayes and McColloch (loc. cit.).

TABLE II.

The Length of the Pupal Stage of *Anomala kansana.*

	Year	Number Reared	Maximum Days	Minimum Days	Average Days
Collected grubs...	1922	153	20	9	12.5
Collected grubs...	1923	43	17	8	9.9
Reared grubs......	1922	16	12	8	10.

EXPLANATION OF PLATES.

Anomala kansana H. and McC.

Figs. 1, 2, 26, 27, 28, 29, and 30 drawn by Mr. Carl Mohr, others by the author.

PLATE XI

Fig. 1. Nearly mature third instar larva—ant. antenna, as. anal slit, es. epicranial suture, f. front, l. labrum, md. mandible, mp. maxillary palpus, pc. preclypeus, psc. postclypeus, r. radula, Nos. I–III thoracic segments. Nos. 1–10 abdominal segments.

Fig. 2. Ventral aspect of the last two ventral abdominal segments showing the group of spines and setæ on segment ten forming the rake or radula. as. anal slit, r. radula.

Fig. 3. Prothoracic spiracle of the sinstral pleuron. b. bulla, p. peritreme.

Fig. 4. Claw of prothoracic leg. cl. claw, tb. tibia, s. seta.

Fig. 5. Dextral aspect of the head capsule with the mouthparts removed. ant. antenna. two basal segments only, es. epicranial suture, f. front, g. gena, l. labrum, mla, maxillaria or maxillary pleurite, oc. occiput, opg. occipito-postgenal suture, pc. preclypeus, pcl. precoila or mandibular condyle, pg. postgena, prc. paracoila or maxillary articulation, psc. postclypeus, ptc. postcoila or mandibular acetabulum. v. vertex.

Fig. 6. Cephalic aspect of the head and mouthparts. ant. antenna, es. epicranial suture, f. front, fcs. fronto-clypeal suture, l. labrum, md. mandible, pc. preclypeus, pcl. precoila, psc. postclypeus, v. vertex.

Fig. 7. Dextral aspect of the mouthparts *in situ.* The labrum is removed and the labium is concealed by the maxilla. Lettering of the head capsule as in figure 5. cd. cardo, m. maxilla, md. mandible, ms. maxillary scraper, pa. preartis articulating with the condylar precoila (pcl), pta. postartis articulating with the acetabular postcoila (ptc), pra. parartis an articulation of the maxilla at prc.

Fig. 8. Antenna showing sense pits (sp) at distal end.

Fig. 9. Prothoracic leg. cx. coxa, tr. trochanter, fm. femur, tb. tibia, cl. claw.

Fig. 10. Metathoracic leg. Letterings as in figure 9.

Plate XII

Fig. 11. Cephalic aspect of the sinstral mandible. ac. acia, b. brustia, dt. dentes, et. extensotendon, mo. molar area, sb. scrobe, sc. scissorial area. pa. preartis. rt. rectotendom.

Fig. 12. Cephalic aspect of the dextral mandible, lettering as in figure 11.

Fig. 13. Epipharynx on the ental aspect of the labrum and clypeus with the hypopharynx (hc) showing its attachment to the clypeus (cl). pc. precoila, t. torma.

Fig. 14. Caudal aspect of the dextral mandible showing the stridulating area (sa) ac. acia, dt. dentes, mo. molar area, pta. postartis, sc. scissorial area, x. lobe-like prominence which abuts against the hypopharyngeal chitinization.

Fig. 15. Caudal aspect of the sinistral mandible. Lettering as in figure 14 with the addition of et. extensotendom, and rt. rectotendom.

Fig. 16. The vental aspect of the hypopharyngeal chitinization (hc). ph. pharynx. The irregular areas on the lateral margins of the hypopharyngeal chitinization shows its adaptation for fitting snugly into the molar area of the mandibles. r.a semi-membranous setaceous area.

Fig. 17. The ball and socket articulation of the mandible in the region of the clypeus. pcl. precoila, pa. preartis.

Fig. 18. The articulation of the maxilla to the postgena (pg). pra. parartis, prc. paracoila.

Fig. 19. Ventral aspect of the hypopharyngeal chitinization (hc) showing its relation to the closed mandibles (md) x, as in figure 14, pta. postartis. At r. the setaceous area shown in figure 16 is covered by the overlapping of the mandible.

Fig. 20. Caudal aspect of the dextral maxilla. ac. alacardo. cd. cardo, lc. labacoria, m. mala, mp. maxillary palpus, pf. palpifer, ps. parastipes or subgalea, pra. parartis, sc. subcardo, s. stipes., Stippled area is membranous.

Fig. 21. Cephalic aspect of the dextral maxilla. Lettering as in figure 20. ms. teeth of maxillary scraper.

Fig. 22. Caudal or ectal aspect of the labium. lg. ligula or fused glossæ and paraglossæ, lp. labial palpus, mt. mentum, mx. membrane and cardo of the maxilla, sm. submentum, st. stipulæ.

Fig. 23. Distal aspect of labrum showing its assymmetry and rugose surface.

Fig. 24. Single tooth of maxillary scraper of the sinstral maxilla.

Fig. 25. Six teeth comprising the maxillary scraper of the dextral maxilla. (see figure 21).

Plate XIII

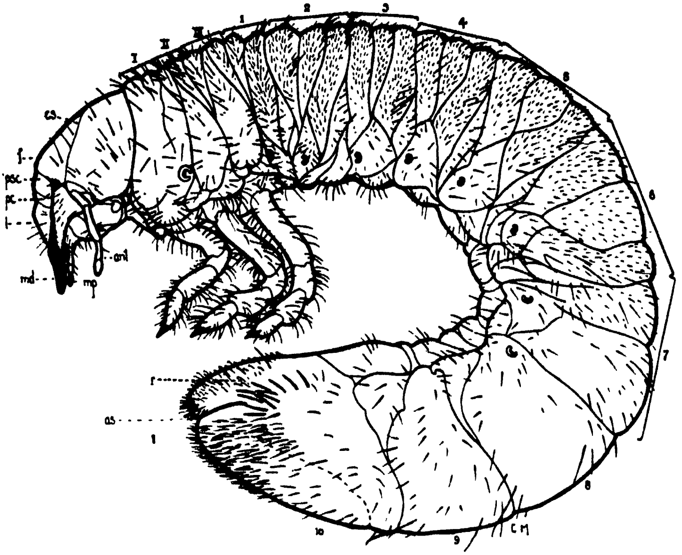
Fig. 26. An egg near the end of embryonic development showing its broadly ovate form.

Fig. 27. A first instar larva soon after hatching. Roman numerals indicate thoracic segments and arabic numerals show the extent and number of annulets of the abdominal segments.

Fig. 28. A second instar larva. Lettering as in figure 1. Numerals as in figure 27.

Fig. 29. Ventral aspect of the pupa, al. anal slit. ant. antenna, ce. compound eye, clp, clypeus. f. front, fw. fore-wing, gt. genetalia, hw. hind wing, lb. labrum, la. labium, md. mandible, ml. mesothoracic leg. mtl, metathoracic leg, mp. maxillary palpus, mx. maxilla, pl. prothoracic leg, pt. prothoracic terga, st. sternum of thorax, tb. tibia, ts. tarsus. Figures 1-7, abdominal sternites.

Fig. 30. Dorsal aspect of adult male *Anomala kansana.*



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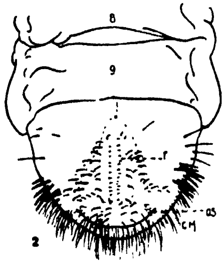

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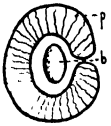

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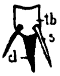

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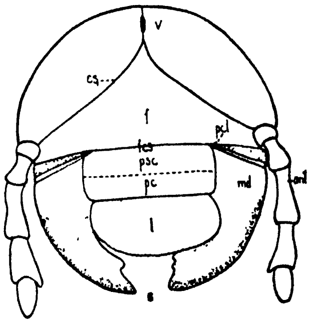

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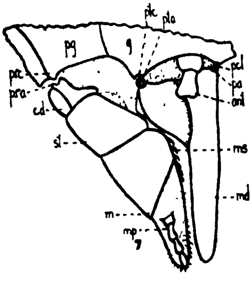

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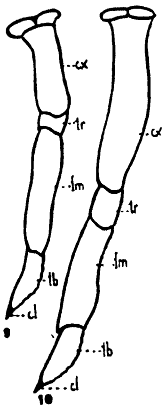

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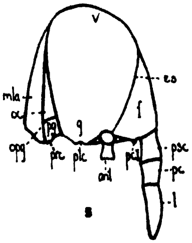

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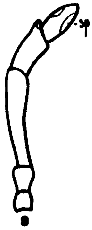

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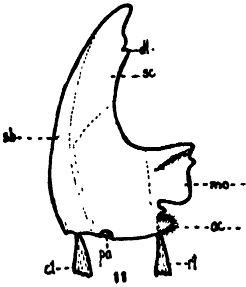

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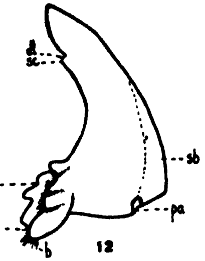

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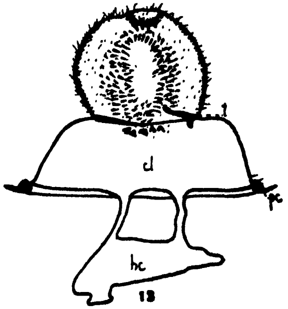

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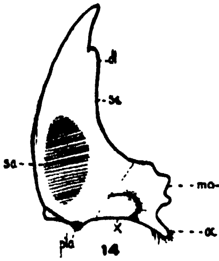

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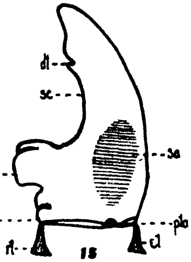

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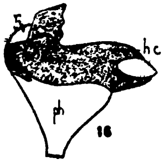

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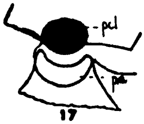

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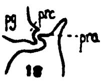

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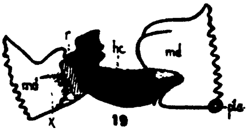

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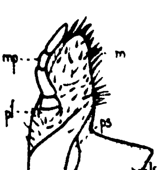

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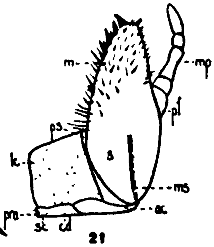

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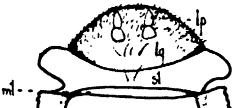

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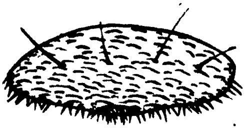

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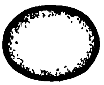

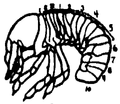

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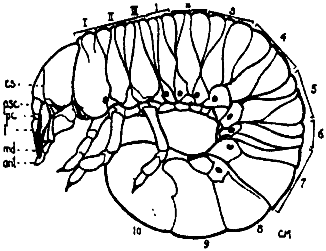

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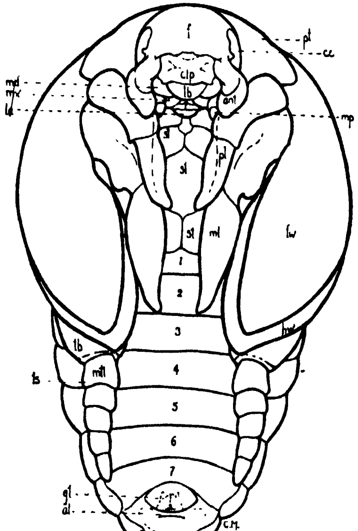

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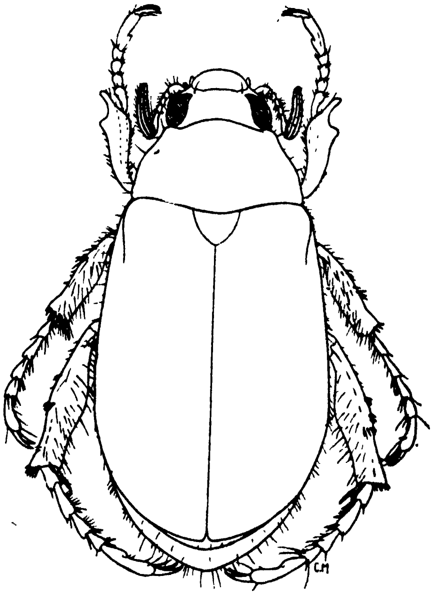

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Wm. P. Hayes

EXPERIMENTAL DATA ON THE OLFACTORY SENSE OF COLEOPTERA, WITH SPECIAL REFERENCE TO THE NECROPHORI.

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Johns Hopkins University.

INTRODUCTION.

When Forel (1908) stated that the olfactory sense of insects was located in the antennæ, his declaration was accepted by the majority of entomologists. More recent discoveries have made it necessary to modify this view. McIndoo (1914, '15, '17, '20) claims that the olfactory sense is located on the bases of the legs and wings. With the exception of one case (1917), McIndoo's morphological studies were supplemented with physiological tests. McIndoo maintains that the removal of antennæ does not obliterate the olfactory sense, but that multilation so disturbs the animal that its responses are not normal. His experimental work is very well done; the greatest objection to it is the artificial set of conditions under which the experiments were made.

Hartwell (1914), accepting McIndoo's dictum concerning the effects of mutilation, tested termites whose antennæ had been treated with cocain hydrochloride and with chloral hydrate. She found that, in a few cases, insects so treated did not respond normally to odors. She was also able to demonstrate the presence of pores on the antennæ. Her results are not complete.

In 1921 von Frisch published the results of some remarkable experiments with bees. His method was to test the responses of bees trained to respond to certain odors, and to test the same individuals after the removal of their antennæ. He found that, in most cases, the bees without antennæ did not recognize the odors. He denies that mutilation, if carefully done, has any lasting effect on the behavior of the insects.

Minnich (1924) conducted experiments on the chemical senses of *Pieris rapæ*. His results seem to indicate that the olfactory sense of these butterflies is located chiefly, but not exclusively, in the antennæ.

My experiments were made with the object of employing conditions as nearly normal as the limitations of the laboratory would permit. The more artifical form of experiment was also used. Efforts were made to determine the most effective methods of eliminating olfactory areas, the possible location of such areas, and the degree of sensitiveness of this sense in the Necrophori.

MATERIAL AND METHODS.

The beetles used in the following experiments were *Necrophorus americanus* (Oliv.), *N. orbicollis* (Say), *N. tomentosus* (Weber), *Silpha inaequalis* (Fab.), and *Trirhabda canadensis* (Kirby). The Necrophori were taken early in June by means of glass jars containing meat buried in the ground to their necks. The beetles were kept in a large wooden box, 17 x 27 inches in extent, and about 10 inches in depth. The box was filled to a depth of 2 inches with clean sand, and was covered with wire screen. The insects were fed decaying flesh; this was also used in some of the experiments. Skatol was also employed experimentally, especially in the determination of olfactory sensitiveness. Test substances were always buried, and tests conducted at night. These precautions were observed in order to eliminate any possibility of the influence of vision in the reactions of the beetles, and also because the Necrophori are chiefly nocturnal.

In the treatment of antennæ three methods were used. In some cases the organs were immersed in cocain hydrochloride (.0032 gms. in 100 c.c. H 2 O) for approximately a minute. The antennæ of other specimens were covered with shellac—or removed entirely. To eliminate the possible olfactory sense of the wing bases, the wings were removed and the points of attachment were covered with shellac. The elytra of the Necrophori and Silphæ were not removed; the small size of *T. canadensis* made the removal of these appendages necessary. It was impossible, of course, to treat the bases of the wings without also covering the bases of the elytra with shellac. To repress possible olfactory senses in the coxæ and trochanters, the bases of the legs were covered with shellac. Various combinations of these methods were also used to prevent stimuli from acting on two or more of the possible olfactory areas.

Although the specimens of *S. inaequalis* were kept in the cage with the Necrophori they were not used in the same experiments. Tests in which these specimens were used were made with individuals. Individual specimens were treated in various ways, and the reactions of these individuals were compared. Some specimens of Necrophorus were also tested in this way.

The experiments with *T. canadensis* were conducted in a somewhat different manner. A number of the insects were kept in a small cage similar to the one used for the Necrophori. The beetles were fed with the leaves of some species of Solidago. Individuals to be tested were removed from the cage and treated to eliminate some possible olfactory organ or organs. The methods of treatment were the same as those employed with the Necrophori. The three substances used in testing the responses of the beetles were the essential oils of clove, bergamot, and almond. A match soaked in one of these substances was brought within a few millimeters of the insect. If no response took place within thirty seconds, the evidence was considered negative. There was no indication that these results were influenced by vision; beetles did not respond to the approach of an unscented object unless actually touched. The usual method was to treat the same organs of ten insects, and to test all of them with the three essential oils. In some cases, however, a few insects succumbed to treatment before the tests could be applied. No attempt was made to keep the individuals distinct. When the experiments were completed, the ten beetles were discarded, and another group was used for the following series of tests. Similar methods were used in testing *S. inaequalis*, excepting that a greater variety of test substances were employed. It was found impractical to test specimens of *T. canadensis* with more than one treated body area, especially when shellac was used. Individuals so treated were visibly affected; many died in a few minutes. Even in the case of beetles with only one set of organs covered, few survived the operation more than two days. Had this altered their responses the results of the experiments might well be questioned, but, as will be pointed out later, such was not the case.

The untreated specimens of *T. canadensis* were all alive and active when released at the end of the period of experimentation. The death of a number of the Necrophori during the course of the experiments seemed to be due rather to confinement than to mutilation. In fact many Necrophori, both normal and treated specimens, lived until the termination of the period of experimentation. This was about six weeks.

RESULTS.

The nature of the experiments in which the Necrophori were employed makes a certain amount of repetition unavoidable.

On the evening of June 20th the antennæ of four specimens of *N. americanus* and two of *N. orbicollis* were immersed for one minute in a solution of cocain hydrochloride. The antennæ of another specimen of *N. orbicollis* were removed. The insects were marked by cutting off part of one elytron. Five minutes later one treated specimen of *N. americanus* was feeding on a piece of meat. The artificial light drove it away, but fifteen minutes later a treated individual of *N. americanus* was feeding on the meat. A little later it was joined by another treated specimen of the same species.

On June 21st, at 6.30 P. M., the antennæ of three specimens of *N. americanus* were again treated with a solution of cocain. At 8.30 one of them was feeding on the meat. At 9.15 two *N. americanus* and two *N. orbicollis* were similarly treated, and the antennæ of another specimen of *N. orbicollis* were removed. At 10 P. M. one treated specimen of *N. americanus* and two of *N. orbicollis* with no antennæ were feeding on the meat. At 7.15 the antennæ of three specimens of *N. americanus* and two *N. orbicollis* were covered with shellac. A fragment of meat was wrapped in a cloth and buried in the middle of the cage, At this time four beetles were feeding on other pieces of meat scattered about the box. Two were normal specimens of *N. orbicollis;* there was also a specimen of *N. orbicollis* with no antennæ and one of *N. americanus* with antennæ covered with shellac. At 9.50 one specimen of *N. orbicollis* and one of *N. americanus*, both with antennæ covered with shellac, were found on the meat. A specimen of *N. orbicollis* with no antennæ was also feeding.

On June 24th one specimen of *N. americanus* and one of *N. orbicollis*, both treated with shellac, were found on the meat. At 8.25 P. M. the antennæ of two specimens of *N. americanus* and of three specimens of *N. orbicollis* were covered with shellac.

At 10 P. M. all pieces of meat were removed from the cage, with the exception of a large fragment that was buried in the sand. By 10.15 three specimens of *N. americanus* were digging for the meat. Two had antennæ covered with shellac; the third had no antennæ.

At 8.30 P. M. of the 25th, four specimens of *N. americanus* and two of *N. orbicollis* without antennæ were found under the unearthed meat. Three of the specimens of *N. americanus* had treated antennæ. There was also a specimen of *N. orbicollis* with its antennæ covered with shellac, as well as four normal specimens of the same species. At 9.45 P. M. the wings of two specimens of *N. americanus* were removed, and the bases of the legs covered with shellac. Four specimens of *N. orbicollis* were similarly treated. The meat was buried in another part of the cage.

On the 26th, at 7.10 A. M., one specimen of *N. orbicollis* treated on the previous day was found on the meat. At 1 P. M. it was joined by a normal specimen of *N. americanus* and one of *N. orbicollis* with no antennæ.

On the 27th the meat was removed, and a cloth saturated with a .00036 of one percent solution of skatol was buried in the sand. This was done at 1.20 P. M. At 1.45 two beetles were digging for the cloth, and at 2.16 this number had increased to five. One of these was a specimen of *orbicollis* without wings and the leg bases covered with shellac. At 9. P. M. the cloth was removed, and a similar piece, saturated with a .00018 of one percent solution of skatol was buried in another part of the cage. At 9.20 two specimens of *N. americanus* were digging for it; by 9.45 it was unearthed by seven beetles that were trying to eat it. Two were normal specimens of *N. orbicollis*, two were normal specimens of *N. americanus*, two were specimens of *N. orbicollis* without antennæ, and one was a specimen of *N. americanus* without antennæ.

At 6.30 P. M. of the 28th a cloth soaked in a .00009 of one percent solution of skatol was buried in the cage. It was undisturbed on the 29th, and on the morning of the 30th it was removed. At 10 P. M. of the same day a cloth saturated with a skatol solution of the same percentage was buried in the sand. On July 1st, at 9 A. M., it was exposed by a normal specimen of *N. orbicollis* and a specimen of the same species without antennæ. At 5.55 of the same day a cloth saturated with a .00004 of one percent solution of skatol solution was buried in the box. It was untouched on the morning of July 2nd.

TABLE I.

N. americanus.

Date and Condition of Insect	Test Substance	Response Time	Response
July 3rd Normal	pyridine	5 seconds	moved away
	almond	20 seconds	moved away
	clove		no response
	skatol	5 seconds	moved antennæ
July 3rd No antennæ; no wings	pyridine	10 seconds	moved away
	almond	15 seconds	moved legs and head
	bergamot		no response
	skatol	15 seconds	moved toward
July 3rd No wings; legs treated	pyridine	immediate	moved away
	clove		no response
	almond		no response
	skatol	10 seconds	rubbed antennæ
July 4th No wings; legs treated	pyridine	immediate	moved away
	clove	5 seconds	moved away
	almond	5 seconds	moved away

N. orbicollis.

Date and Condition of Insect	Test Substance	Response Time	Response
No record of date Normal	clove	10 seconds	moved antennæ
	pyridine	15 seconds	dug into sand
	skatol	10 seconds	no record
	almond	5 seconds	moved away
July 4th No antennæ	pyridine	15 seconds	moved away
	clove	5 seconds	rubbed mouth
	almond	immediate	moved away
	skatol	10 seconds	chewed stick
July 4th No antennæ no wings; legs treated	pyridine	immediate	moved away
	bergamot	immediate	moved away
	clove	43 seconds	moved away
	skatol	30 seconds	moved toward

On July 2nd a cloth soaked in a .00009 of one percent solution of skatol was buried in the box. On the morning of the 3rd it was still untouched.

On July 4th a piece of decaying meat was put into a flower pot, which in turn was placed ten feet above the ground in a tree. On the morning of the 5th a specimen of *N. tomentosus* was found on the meat. On the morning of July 7th the flowerpot was replaced, and a second fragment of meat was placed four feet above ground in a pile of bricks. Near midnight

TABLE II.

Silpha inaequalis.

Date and Condition of Insect	Test Substance	Response Time	Response
July 10th Normal	pyridine	immediate	moved legs; antennæ
	almond	2 seconds	moved away
	clove	20 seconds	moved away
	isosafrol	15 seconds	moved away
July 11th Normal	almond	immediate	moved away
	pyridine	immediate	moved away
	bergamot	5 seconds	moved away
July 10th No antennæ	pyridine	5 seconds	moved away
	almond	5 seconds	moved away
	clove		no response
	isosafrol		no response
July 11th	almond		no response
	pyridine		no response
	bergamot	no record	moved away
July 10th No antennæ; no wings legs treated	pyridine	10 seconds	moved head; legs
	almond	25 seconds	moved away
	clove		no response
	isosafrol		no response
July 11th No antennæ; no wings; legs treated	almond	10 seconds	moved away
	pyridine		no response
	bergamot	2 seconds	moved away
July 10th No wings; legs treated	pyridine	10 seconds	moved away
	almond	immediate	moved away
	clove	10 seconds	moved away
	isosafrol		no response
July 11th No wings; legs treated	almond	immediate	moved legs; antennæ
	pyridine	5 seconds	moved legs; antennæ
	bergamot	5 seconds	moved legs; antennæ

of the 8th, an aberrant specimen of *N. tomentosus* was taken in the bricks, and a normal specimen was found in the flower-pot on the 9th. Most of the meat used in taking specimens of *N. tomentosus* was nearly fresh.

In the cage was one specimen of *N. americanus* which had no antennæ and no wings, and the leg bases of which were covered with shellac. It invariably found buried meat in a few hours.

TABLE III.

Trirhabda canadensis.

Date and Condition of Insects	Test Substance	Response		Notes
		No. +	No. —	
July 17th Normal	clove bergamot almond	10 9 10	0 1 0	
July 18th No antennæ	clove bergamot almond	8 10 9	2 0 1	
July 19th No wings	clove bergamot almond	10 5 8	0 3 0	 8 tested 8 tested
July 22nd Legs treated	clove bergamot almond	4 4 8	6 4 2	 8 tested
August 3rd Antennæ cocainized	clove bergamot almond	10 9 9	0 1 1	

The accompanying tables represent individual tests in which Necrophori and Silphæ were used.

No attempt has been made to record the exact responses of *Trirhabda canadensis.* Beetles that failed to respond, or that did not respond within thirty seconds were marked negative; those responding within the time indicated were considered positive.

DISCUSSION.

It is evident from these experiments that mutilation does not produce as unreliable results as has often been assumed. In the case of *T. canadensis* particularly, abnormalities produced by mutilation in no way altered the responses of the insects to chemical stimuli. The similarity of response from beetles differently treated was wholly unexpected. One specimen of *N. americanus* with neither wings nor antennæ remained active and normal to the end of the experiments. Specimens of *T. canadensis* in dying or abnormal conditions responded almost as readily as normal insects.

Anaesthetization is not as effective as mutilation for the elimination of sensation. It is a method which cannot be used on the harder chitinous parts.

In these experiments, the antennæ certainly showed little evidence of being the seat of the olfactory sense. It would be unwise to state that no olfactory organs are located in the antennæ, but that such organs should be restricted to those appendages seems unreasonable. The destruction of the antennal sense, as well as that of the legs and wings, certainly did lengthen the reaction-time in some cases. But, as both the experiments in the cage and with the essential oils proved, it did not wholly exclude odors from the beetles. The attempt to localize the olfactory organs of insects appears to be founded on the fact that in mammals and similar animals such senses are thus localized. Experiment does not indicate that among insects such is the case. It is probable that olfactory organs do occur both in the antennæ and the areas indicated by McIndoo (1915). But it is probable that there is also a more general distribution of the chemical sense over the body of insects. Minnich (1924) seems to have anticipated this conclusion.

The olfactory powers of the Necrophori are certainly remarkable. A specimen of *N. americanus* with neither wings nor antennæ detected and unearthed in half an hour a rag soaked in a .00009 of one percent solution of skatol. All this was done in absolute darkness. Normal specimens of *N. tomentosus* detected meat which was slightly stale and almost certainly placed in situations far from their immediate habitat. Add to this the fact that the Necrophori smell so strongly of putrid flesh that they are positively offensive, and it becomes evident that these insects possess a chemical sense which is almost unique.

The more artificial experiments, including those with *T. canadensis*, corroborated the evidence from the caged Necrophori.

CONCLUSIONS.

1. *Necrophorus americanus* and *N. orbicollis* were not greatly affected by mutilation through the removal of wings, antennæ, or by treatment with shellac.

2. *Silpha inaequalis* and *Trirhabda canadensis* were seriously affected by treatment with shellac, but that did not influence their responses to chemical stimuli.

3. Anaesthetization proved to be a fairly reliable experimental method.

4. Removal of wings and the use of shellac on leg bases lengthened the reaction-time of some of the Necrophori and Silphæ.

5. The various methods of treatment did not prevent final responses in the Necrophori.

6. The various methods of treatment did not appreciably alter the reaction-time of *T. canadensis*.

7. Normal specimens of *N. tomentosus* detected comparatively fresh meat at considerable distances.

9. *N. americanus* and *N. orbicollis* responded, even when treated, to skatol in dilutions of .00009 of one percent.

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THREE NEW SPECIES OF PHYTOMYZA.
(Agromyzidæ, Diptera).

S. W. Frost,
Penn. State College.

The following new species are added to those previously described by the writer (1924)* in "A Revision of the North American Species in Phytomyza Fallen." They run in that key as indicated in the accompanying descriptions. The Holotypes have been deposited in the U. S. National Museum.

Phytomyza auricornis n. sp.

A medium size species, 3 to 3½ mm. Front, face, cheeks and antennæ entirely yellow; arista brown; palpi yellow, infuscated at tips, setæ of palpi black; proboscis and setæ yellow; orbits concolorous with front, darkened on upper portion; ocellar triangle subshiny brown, continuous with occiput which is likewise subshiny brown; cheeks about three quarters eye height, yellow of cheeks extending back of eye but intercepted at vertex by brown of the back of the head; front slightly broader than either eye, somewhat produced at the insertion of the antennæ, sides converging below; four pairs of fronto-orbital bristles, the lower pair very short and weak, a sparse row of small setæ on orbits adjacent to eye margin, barely reaching the upper fronto-orbital bristles; a row of small setæ on outer hind edge of head continuing down hind margin of cheek; a single pair of oral vibrissæ, scarcely stronger than the accompanying setæ along the lower margin of the cheek; basal segments of the antennæ entirely yellow, second segment with a dorsal black spine and a weaker ventral spine, third segment yellow, scarcely longer than broad, rounded at tip, covered with short yellow pile, arista 2½ times as long as third antennal segment, brown, microscopically pubescent, thickened on basal third. Mesonotum and scutellum cinerous; four pairs of dorso-central bristles, all about the same size, first and second pairs and third and fourth pairs approximated in their rows, dorso-centrals preceeded by a few small setæ, three or four irregular rows of acrostichals reaching three-quarters of the way to the scutellum, a few small setæ outside the dorso-centrals, four scutellar bristles; sides of mesonotum cinerous, pleural sutures narrowly yellow, 2 presutural, 1 mesopleural, 1 sternopleural and 1 propleural bristle. Abdomen subshiny brown, last segment ♀, shiny black nearly one half as long as the base of the abdomen. Legs brown, knees pale yellow. Wings slightly infumed, rounded at tips, veins pale brown,

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*Cornell Memoir No. 78:58-90. 1924. The inclusion of *P. betæ* Coq., at that time was an error. It occurs only in Tasmania, Australia.

vein 1 bends towards the anterior margin of the wing, veins 2 and 3 are subparallel, veins 3 and 4 diverge through their entire course, vein 4 is nearly straight ending slightly beyond the tip of the wing, vein 5 bends gently into the wing margin; second, third and fourth sections of costa as 3-1-1½ or 2; anterior cross vein about one and a half times its length from the division of veins 2 and 3; halteres yellow, calypteres and fringe pale brown.

Holotype ♀, collected by Henry Dietrich, Freeville, N. Y. June 5, 1917. The species runs out at couplet 15, writers key*. It is close to *P. flavicornis* Fall., but the lower fronto-orbitals are weak and there are three or four rows of acrostichals. Food habits unknown.

Phytomyza angelicella n. sp.

A medium size species, 2½ to 3 mm. long. Front and cheeks largely yellow; proboscis and setæ yellow; palpi black; antennal grooves dark brown, oral margin narrowly yellow; cheeks about one half eye height, narrower in front than behind, yellow of cheek continuing back of eye but intercepted at vertex by black of back of the head; orbits concolorous with front but darkened along margins of eyes and especially on upper angles; ocellar triangle subshiny brown continuous with the black of the back of the head, (the so called ocellar triangle is quadrate in shape), back of head subshiny black above, yellow below on outer edges; front somewhat wider than either eye and slightly narrowed below, not at all produced at the insertion of the antennæ; four well developed pairs of fronto-orbital bristles, a fifth weak pair below; an irregular row of small setæ on orbits adjacent to eye margin, extending from the lower fronto-orbital to the vertical bristles tending to form two rows above, some occuring in line with the fronto orbitals (the holotype shows two small setæ on the upper angles of the front), a distinct row of small setæ on the outer margin of the back of the head continuing down the hind margin of the cheek; oral vibrissæ scarcely longer than the accompanying setæ along the lower margin of the cheek; antennæ black, at most the basal segments dark brown, second segment with a dorsal spine, third segment slightly longer than broad, rounded at tip, microscopically pubescent, arista about twice as long as third segment, thickened on the basal third, microscopically but distinctly plumose. Mesonotum and scutellum cinerous, slightly shiny; four pairs of moderately strong dorso-central bristles, first and second pairs approximated in their rows and slightly smaller than the posterior pairs, three or four sparce irregular rows of acrostichals extending about half way to the scutellum, some small setæ in the row with the dorso-centrals, a few scattered setæ outside dorso-centrals, pleural sutures broadly yellow but color not extending on humeral callosities, 1 strong humeral, 1 postalar, 1 supraalar, 1 sternopleural, 1 mesopleural, 2 presutural, and 1 propleural bristle. Abdomen ♂, subshiny brown,

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**Loc. cit.*

somewhat pale yellow on sides of basal segments, male genetalia chiefly shiny brown, centrally divided by a narrow pale yellow line; ♀ similar, genetalia shiny black. Legs brown including tarsi, tips of femur pale yellow. Wings hyaline, rounded at tips, 1st vein yellow slightly beyond humeral cross vein, veins pale brown, costa extending considerably beyond the termination of vein 3, vein 2 bending distinctly towards the anterior margin of the wing then terminating subparallel with vein 3, veins 3 and 4 diverging gently from base of wing to apex, vein 4 nearly straight and ending slightly beyond the tip of the wing, second, third and fourth sections of costa as 3–1–1½, vein 5 bending gently into the margin of the wing, anterior cross vein about 1½ times its length from the division of veins 2 and 3 and distinctly before the termination of vein 1, halteres pale yellow, edge of calypteres and fringe dark brown.

Holotype ♂, reared from *Angelica atropurpurea* by Mr. A. S. Mills at Ithaca, N. Y. He states that the larvæ make linear mines on the upper sides of the leaves. The writer has in addition 9 paratypes; 7 ♂, 2 ♀ from Ithaca, N. Y. This species runs close to *P. albiceps* Meig., (Couplet 39).* It differs chiefly in the presence of a fifth weak fronto-orbital and the abundance of small setæ on the orbits.

Phytomyza marginalis n. sp.

A medium size species, 2½ to 3 mm. long. Front, cheeks and proboscis yellow, palpi black; orbits distinctly darkened or cinerous along the margin of the eye and especially on the upper angles; ocellar triangle cinerous and continuous with the cinerous color of the back of the head; front one and a half times as wide as either eye, slightly longer than broad and protruding slightly at the insertion of the antennæ; antennal grooves darkened, a narrow yellow line on oral margin; cheeks one and a half eye height, slightly narrower in front than behind, somewhat darkened on upper part and yellow color not extending back of eye; four slender pairs of fronto-orbital bristles, sometimes with a weak fifth pair, the lower two pairs approximated in the row, pointing downward and inward, the upper pairs pointing upward; a sparse row of small setæ on orbits adjacent to eye margin, scarcely reaching the upper fronto-orbital; a single row of small setæ on the outer edge of the back of the head; antennæ entirely black, third segment slightly longer than broad and rounded at the tip, sparcely covered with short brown pile, arista twice as long as third segment, subshiny, microscopically pubescent and thickened on the basal third. Mesonotum and scutellum cinerous; four pairs slender dorso-central bristles, first two pairs approximated in the rows, two rows of well developed acrostichals, five to six setæ in a row, several small setæ outside dorso centrals on anterior part of mesonotum; sides of mesonotum cinerous, pleural sutures narrowly yellow; 1 humeral, 1 supraalar, 1 postalar, 1 propleural,

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**Loc. cit.*

1 strong mesopleural, 1 sternopleural and 2 presutural bristles. Abdomen subshiny brown, last segment ♀ shiny black lightly dusted and nearly three quarters the length of the base of the abdomen. Legs subshiny brown, knees narrowly pale but scarcely yellow. Wings slightly infumed, costa extending only slightly beyond the termination of vein 3, veins 2 and 3 diverging at base but subparallel on their distal half, veins 3 and 4 distinctly diverging from base to tip, vein 4 straight and ending in the tip of the wing, vein 5 curving gently into the wing margin, second, third and fourth sections of costa as 3–1–2, anterior cross vein about twice its length from the division of veins 2 and 3, and distinctly before the termination of vein 1; halteres pale yellow, calypteres and fringe pale dusky.

Holotype ♀, McLean, N. Y. May 29, 1915, food habits unknown. The writer also has fifteen paratypes; 7 ♀ from McLean, N. Y., 2 ♀ Freeville, N. Y. collected by Henry Dietrich, 4 ♀ and 1 ♂, Ithaca, N. Y. and 2 ♂ McLean, N. Y. Although this species runs to couplet 36 in the writers key*, due to the well developed acrostichals, it is more closely related to *P. chrysanthemi* Kowarz. It differs from *chrysanthemi* however in the presence of four or five fronto-orbitals, well developed acrostichals and the distinctly margined orbits.

Loc. cit.

A NEW SPECIES OF PHYLLOPHAGA FROM MISSISSIPPI.*

J. M. Langston,
A & M College, Miss.

Several years ago while examining specimens of *Phyllophaga* from student collections a few males were found that we were unable to determine. There was one specimen from the 1915 and one from the 1919 collections. During 1923 a few specimens of both sexes were found in student collections. One of these collections was made by Mr. J. Gunby, who lives several miles west of A & M College, Mississippi. This species did not appear in any other collection examined by the writer until the spring of 1926. On April 18, 1926 a number of male specimens were collected about five miles southwest of A & M College by two students, Mr. J. E. Williamson and Mr. H. E. Woodruff. The specimens were seen flying about one hour before dark and captured with an insect net. Later specimens of this species were found in the collections of six other students. This seems to be an undescribed species and a description of it is given below.

Phyllophaga davisi n. sp.†

This species belongs to group XV and runs to the species *affabilis* in Horn's key, with the exception that the inner spurs of the hind tibiæ are not short. The genitalia of the male, however, is not the same as that given for that species by Smith (Proceedings U. S. National Museum, Plate LX, Figure 80).

Body oblong-oval, widest about middle of elytra, color chestnut brown, head slightly darker, some specimens with head and thorax darker, female slightly darker than the male, surface shining. Clypeus concave, margin narrowly reflexed, very slightly emarginate, punctures moderately close in the male, sometimes more sparsely placed at sides, not so close in the female. Front not so densely punctured anteriorly as the clypeus, punctures closer posteriorly than on clypeus or thorax in most specimens. Thorax narrowed in front, widest slightly before the middle, sides curved and slightly sinuate before the hind angles, margin entire and sparsely ciliate, punctures near the anterior margin as closely placed as those on clypeus, more sparsely placed on the remainder of the surface with numerous smooth spaces. There is a vague depressed area near each of the hind angles and in some specimens a smaller one on each side about half way between the hind angles and the disk near the posterior margin. Elytral punctures not so well defined but denser than those of thorax, sometimes slightly rugose especially near the umbone; sutural and discal costæ moderately prominent, submarginal prominent on some specimens, others not so prominent; a broad shallow depression on base of elytra between scutellum

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*Contribution from the Mississippi Experiment Station.

†The species is named in honor of Prof. J. J. Davis, Purdue University, La Fayette, Indiana in appreciation of the interest he has taken in the study of the *Phyllophaga* of Mississippi and his willingness at all times to aid in the determination of our species.

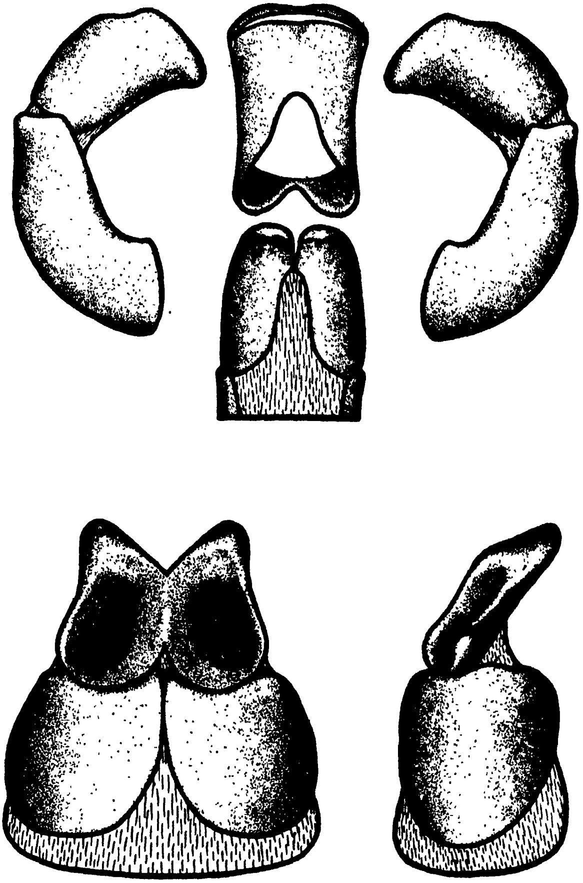

FIGURE 1.

Phyllophaga davisi n. sp. Male and female genitalia both enlarged, the enlargement of the female greater than that of male.

and umbone. Pygidium sparsely and indistinctly punctured, moderately shining. Metasternum densely covered with shallow punctures and moderately hairy in the male, less densely and more distinctly punctured and only slightly hairy in the female. Abdomen sparsely and indistinctly punctured. Tarsal claws curved, tooth small and intramedian in the male, larger and median in the female. Last joint of maxillary palpi somewhat oval, the length twice the width, not at all or very slightly impressed. Length 11-12 mm.; width 5.5-6 mm.

Male—Antennæ 9-jointed, club very slightly shorter than the stem. Abdomen not flattened beneath but with a broad shallow depression extending the full width of the last two segments. This depression is limited anteriorly by a faint curved ridge the ends of which extend diagonally about one-half the width of the penultimate segment. Posterior to this line the depression bears numerous irregular elevations on the penultimate segment and a roughened space at middle of the last ventral. Both hind tibial spurs free the inner three-fourths the length of the outer. The genitalia with claspers symetrical and simple. (See Fig. 1.)

Female—Antennæ 9-jointed, club slightly more than one-half the length of the stem. Hind tarsi shorter than those of the male, hind tibial spurs about same length as those of male. Inner three-fourths the length of the outer.

The type series consists of holotype, male, and seven male and two female paratypes.

Habitat—All of our specimens are from student collections and are labeled A & M College, but it is probable that most or all of them were taken several miles west of A & M College, Mississippi in what is known as the flat woods soil area.

MEGALOPSALLUS, A NEW GENUS OF MIRIDÆ WITH FIVE NEW SPECIES FROM NORTH AMERICA (HEMIPTERA).*

HARRY H. KNIGHT,
Ames, Iowa.

Megalopsallus, new genus.

Allied to *Psallus* Fieb., but head larger, broad, shaped much as in *Lygus* Hahn, or *Phytocoris* of the *pinicola* group. Arolia bristle-like, claws broadly curved, without distinct notch at inner side of base, pseudarolia entirely absent. Genitalia much as in *Plagiognathus* Fieb., but right clasper small, little longer than broad; left clasper with small spine at base of dorsal margin which points in a line parallel with margin of genital segment, this clasper having much the same form and holding the tip of the oedaegus as in *Plagiognathus politus* Uhler; genital characters distinctive for the genus. Pubescence composed of closely matted, sericeous, deciduous hairs, and intermixed with more erect and sparsely set, simple pubescent hairs. Rostrum long, reaching the hind coxæ or longer. Tibial spines pale but usually with fuscous dots at base.

Genotype: Megalopsallus atriplicis n. sp.

This genus runs close to *Psallus* in my key (Hemiptera of Connecticut, 1923, p. 429), but differs in the absence of pseudarolia, differently shaped head, and characteristic genitalia.

Megalopsallus atriplicis, new species.

A small pale greenish species, with broad head, long rostrum, clothed with white sericeous pubescence and intermixed with simple fuscous hairs; length 2.5—2.8 mm.

♂. Length 2.5 mm., width 1 mm. Head: width .71 mm., vertex .326 mm. Rostrum, length 1.18 mm., reaching to middle of venter, pale greenish, apex blackish. Antennæ: segment I, length .20 mm.; II, .77 mm., cylindrical, more slender than segment I; III, .62 mm.; IV, .42 mm., pale greenish, last two segments dusky. Pronotum: length .37 mm., width at base .86 mm.

Uniformly pale greenish, eyes reddish brown; femora with numerous small setigerous fuscous dots; tibiæ pale, spines brownish to dusky, each with a fuscous dot at base, becoming obsolete apically, tarsi pale, claws black; membrane whitish, veins concolorous, a distinct fuscous spot at basal angle of larger areole, smaller areole dusky to fuscous, apical half of membrane more or less dusky. Clothed with silvery, sericeous pubescence, and intermixed with more erect, fuscous simple pubescent hairs; ventral surface and legs with white simple pubescence. Genital claspers much as in *Psallus seriatus* Reut., but right clasper much reduced, only a little longer than broad.

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*Contribution from the Department of Zoology and Entomology, Iowa State College, Ames, Iowa.

♀. Length 2.8 mm., width 1.27 mm. Head: width .80 mm., vertex .43 mm. Antennæ: segment I, length .21 mm.; II, .76 mm. Pronotum: length .46 mm., width at base 1 mm. More ovate and robust than the male but very similar in coloration and pubescence.

Holotype: ♂ April 25, 1926, Brownsville, Texas (T. C. Barber); author's collection. *Allotype:* same data as type. *Paratypes:* 14 ♂ ♀, taken with the types on *Atriplex matamorensis* which is the host plant of the species. Texas: 12 ♂ ♀ Feb. 15, 10 ♂ ♀ Sept. 11, 1925, 6 ♂ ♀ Mar. 24, 1926, Brownsville (T. C. Barber), on *Atriplex matamorensis.* 7 ♂ ♀ June 23, 1908, Brownsville (Hart). 3 ♂ Aug. 15, ♀ Sept. 1, 5 ♂ ♀ Sept. 10, 1925, Port Lavaca (R. H. Painter), on *Atriplex arenaria* and *A. matamorensis.* ♂ Aug. 18, 1922, Interior, S. Dak., (H. C. Severin).

Megalopsallus rubropictipes, new species.

Larger but more slender than *atriplicis*, antennal segment II longer, rostrum shorter, sternum fuscous and femora with reddish.

♂. Length 3.4 mm., width 1.24 mm. Head: width .80 mm., vertex .38 mm. Rostrum, length 1.09 mm., only reaching upon hind coxæ. Antennæ: segment I, length .21 mm.; II, .95 mm., cylindrical, a trifle thicker apically, but not attaining thickness of segment I; III, .66 mm.; IV, .43 mm.; greenish yellow, last two segments dusky. Pronotum: length .43 mm., width at base .96 mm.

Pale yellowish, tinged with green, eyes reddish brown; femora with numerous small reddish dots on apical half, a few fuscous setigerous dots also; tibiæ pale, spines yellowish, each with a light fuscous dot at base, tarsi yellowish, tips and claws blackish; sternum fuscous to black, spot at top of coxal cleft and numerous small dots and points on sides of venter, reddish. Membrane and veins whitish, fuscous spot at base of larger areole, darkened smaller areole and dusky on apical half of membrane nearly as in *atriplicis*. Thickly clothed with silvery, sericeous, deciduous pubescence, and intermixed with more sparsely set brownish to dusky simple pubescent hairs. Genital characters nearly as in *atriplicis*, scarcely to be separated on external examination.

Holotype: ♂ Aug. 17, 1925, Florence, Colorado (H. H. Knight), taken at light; author's collection. *Paratypes:* ♂, taken with the type. ♂ ♀ Sept. 12, Trinidad, ♂ Sept. 14, Rocky Ford, ♂ Sept. 15, 1898, Pueblo Colorado (E. D. Ball). The female is too poor for description.

Megalopsallus latifrons, new species.

Allied to *atriplicis* but larger, membrane uniformly whitish, without fuscous spot at base of larger areole, antennal segment II distinctly longer than width of head; greenish to yellowish, femora with small setigerous fuscous dots; length, 3.3—3.5 mm.

♂. Length 3.3 mm., width 1.36 mm. Head: width .89 mm., vertex .37 mm. Rostrum, length 1.38 mm., reaching upon fourth ventral segment, yellowish, apex black. Antennæ: segment I, length .26 mm.; II, 1.03 mm.; III, .74 mm.; IV, .47 mm.; greenish yellow, last two segments becoming dusky. Pronotum: length .54 mm., width at base 1.12 mm.

Uniformly pale greenish, more yellowish on head, mesonotum, body beneath and legs; femora with small setigerous fuscous dots, becoming obsolete on basal half; tibiæ and spines pale yellowish, a small pale fuscous dot at base of each spine. Membrane uniformly whitish, veins pale to yellowish, without fuscous spot at base of larger areole. Clothed with silvery, sericeous pubescence, and intermixed with more erect, fuscous simple pubescence; ventral surface and legs with simple white pubescence. Genital characters very similar to those of *atriplicis*.

♀. Length 3.5 mm., width 1.5 mm. Head: width .87 mm., vertex .47 mm. Antennæ: segment I, length .24 mm.; II, .92 mm.; III, .71 mm.; IV, .36 mm. Pronotum: length .51 mm., width at base 1.18 mm. More robust than the male but very similar in coloration and pubescence.

Holotype: ♂ Aug. 6, 1925, Delhi, Colorado (H. H. Knight); author's collection. *Allotype:* same data as the type. *Paratypes:* 20 ♂ ♀, taken with the types on the host plant, *Saueda diffusa* Wats. Colorado—♂ Aug. 30, Fort Collins, ♀ July 20, 1898, Delta (E. D. Ball). Mutilated specimens are present from Grand Junction which probably belong here. Texas—♀ Aug. 19, 2 ♂ Aug. 22, 1925, Port Lavaca (R. H. Painter), collected on *Dondia linearis* which is probably another host for the species. ♀ June 25, 1917, Victoria (H. H. Knight).

Megalopsallus latifrons diversipes, new subspecies.

Suggestive of *latifrons* but differs in the longer second antennal segment which nearly equals width of pronotum at base; femora more or less reddish on apical half, fuscous dots not apparent on hind tibiæ at base of the yellowish spines; the simple fuscous pubescence on the dorsum somewhat heavier than in *latifrons*.

♂. Length 3.4 mm., width 1.3 mm. Head: width .89 mm., vertex .41 mm. Rostrum, length 1.4 mm., reaching upon fifth ventral segment. Antennæ: segment I, length .266 mm.; II, 1.06 mm.; III, .89 mm.; IV, .44 mm. Pronotum: length .50 mm., width at base 1.09 mm.

♀. Length 3.8 mm., width 1.6 mm. Head: width .93 mm., vertex .53 mm. Antennæ: segment I, length .266 mm.; II, 1.23 mm.; III, 1 mm.; IV, .44 mm. Pronotum: length .56 mm., width at base 1.27 mm.

Holotype: ♂ June 14, 1917, Biloxi, Mississippi (H. H. Knight); author's collection. *Allotype:* taken with the type at light. *Paratypes:* 22 ♂ ♀, taken with the types at light. The next morning various plants in the same vicinity were swept with the net but without finding this species.

Megalopsallus brittoni, new species.

Distinguished by the long second antennal segment which in length (♂) exceeds basal width of pronotum; form and color of head, especially the broad vertex and large eyes, very suggestive of a female *Phytocoris* of the *pinicola* group, but size smaller.

♂. Length 4 mm., width 1.5 mm. Head: width .95 mm., vertex .43 mm. Rostrum, length 1.66 mm., scarcely attaining posterior margins of hind coxæ. Antennæ: segment I, length .29 mm.; II, 1.33 mm.; III, 1.03 mm.; IV, .53 mm.; yellowish to dusky, last two segments light fuscous. Pronotum: length .55 mm., width at base 1.23 mm.

General coloration pale yellowish to dusky, pronotum, mesoscutum, scutellum, and thorax beneath more reddish, venter more strongly yellow; femora reddish yellow to dusky red-brown, small setigerous fuscous dots apparent; tibiæ pale to dusky, spines pale without fuscous dots at base. Hemelytra pale yellowish, tinged with dusky, somewhat darker apically, cuneus concolorous with corium; membrane whitish, tinged with brownish, areoles somewhat darker, veins tinged with reddish, anal area dark brown bordering vein. Dorsum clothed with silvery, sericeous pubescence, and intermixed rather abundantly with more erect, fuscous simple pubescence; ventral surface and legs clothed with simple pale pubescence. Genital characters very similar to other members of genus, apparently not exhibiting good specific characters.

Holotype: ♂ July 4, 1904, Westville, Connecticut (W. E. Britton); author's collection.

Megalopsallus adustus, new species.

Allied to *brittoni* but second antennal segment shorter, darker colored, the thorax and femora strongly fuscous.

♂. Length 4.1 mm., width 1.5 mm. Head: width .98 mm., vertex .44 mm. Rostrum, length 1.7 mm., attaining posterior margins of hind coxæ, yellowish brown, apex blackish. Antennæ: segment I, length .28 mm.; II, 1.2 mm.; III, 1 mm.; IV, .53 mm.; dusky yellowish brown, darker apically. Pronotum: length .58 mm., width at base 1.24 mm.

Fuscous over a yellowish ground color, thorax, venter and femora darker, sternum more nearly black; basal area of hemelytra lighter, tip of scutellum pale; membrane fuscous brown, more whitish bordering apex of cuneus and between larger areoles. Legs fuscous brown to darker, femora with small setigerous fuscous dots apparent through the dark ground color; tibiæ pale to dusky, spines yellowish, small darker points apparent at base of spines; tarsi dusky brown, claws black. Dorsum clothed with white to yellowish sericeous pubescence, and intermixed with simple fuscous pubescence; sides of thorax and venter bearing silvery, sericeous pubescence and intermixed with simple yellowish pubescence. Genital characters very similar to those of *brittoni*.

♀. Length 4 mm., width 1.5 mm. Head: width .95 mm., vertex .52 mm. Antennæ: segment I, length .266 mm., II, 1.21 mm.; III, 1.03 mm.; IV, .47 mm. Pronotum: length .58 mm., width at base 1.39 mm. Very similar to the male in coloration and pubescence.

Holotype: ♂ October 8, 1918, Anahuac, Texas (H. S. Barber); U. S. National Museum collection. *Allotype:* ♀, taken with the type. *Paratype:* ♀, taken with the types.

KEY TO SPECIES OF MEGALOPSALLUS.

1. Hemelytra, femora, and frequently the body tinged or darkened with fuscous..5
Hemelytra pale to greenish, never darkened with fuscous; femora frequently reddish, or bearing setigerous fuscous dots 2
2. Membrane with distinct fuscous spot on basal angle of larger areole........ 3
Membrane without such fuscous spot 4
3. Antennal segment II equal to, or only slightly exceeding width of head across eyes, being distinctly shorter than basal width of pronotum; length, 2.5–2.8 mm ....**atriplicis** n. sp.
Antennal segment II in length distinctly greater than width of head, nearly or quite equal to basal width of pronotum; length, 3.4–3.6 mm. **rubropictipes** n. sp.
4. Femora pale to greenish yellow, apical half with small, setigerous fuscous dots on anterior aspect; antennal segment II distinctly shorter than basal width of pronotum ....**latifrons** n. sp.
Femora distinctly reddish on apical half; antennal segment II nearly equal to basal width of pronotum ....**diversipes** n. subsp.
5. Antennal segment II of male exceeding basal width of pronotum; hemelytra uniformly tinged with dusky or fuscous, pronotum, scutellum and ventral surface of body lighter, tinged with reddish ....**brittoni** n. sp.
Antennal segment II of male not equal to basal width of pronotum; apical half of clavus and corium distinctly fuscous, pronotum, scutellum, and ventral surface of body dark fuscous ....**adustus** n. sp.

A NEW RABBIT BRUSH APHID FROM UTAH.

George F. Knowlton,*
Utah Agricultural Experiment Station, Logan.

An interesting aphid was found on rabbit brush (*Chrysothamnus viscidiflorus*) in the mouth of Blacksmith Fork Canyon on July 18, 1925. Large colonies of this shining, yellowish-green aphid were present on the tip three to six inches of the branches. The damage consisted of twisting and stunting the tip ends of the twigs, curling the leaves, and stunting the flower heads and their supporting stems. A black fungus on the honeydew-coated foliage seemed to have no effect on the aphids or their host plant. Many curled bushes from past years were dead, and it is common for badly curled, heavily infested branches, or whole bushes, to succumb in early fall.

Durocapillata gen. nov.

Wing venation typical; antennal tubercles moderately prominent; body and appendages armed with prominent bristly hairs most of which are noticeably enlarged at the tip; cornicles large (except in males) cylindrical with pronounced constriction before prominent flange; cauda conical with one or two globate sensilla in addition to the long, tapering ones. Males and oviparous females apterous.

Sub-family: Aphidinæ. Type: *Durocapillata utahensis.*

Durocapillata utahensis n. sp.

Migrants numerous by June 15, 1926, and all had disappeared soon after July 18, considerable spread having occurred. Severe curling occurred on bushes upon which aphids overwintered, with less curling of leaves on plants to which aphids had migrated during the season. The apterous viviparæ were numerous for about a month after egg-laying was in progress, present in the large colonies of oviparous females and less numerous males. Eggs were first observed September 20, the apterous oviparæ and males being numerous at this time. Eggs were deposited in great numbers in captivity, cemented to plant, container, or unattached. A few eggs were found under natural conditions on the rabbit brush cemented to the scales at the base of the flower heads or on the twisted leaves.

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*The writer wishes to express his appreciation to Dr. C. P. Gillette, Miss M. A. Palmer, and Professor O. W. Oestlund for opinions regarding this aphid, while the writer assumes the responsibility for any errors.

Syrphid larvæ, aphis lions, ladybird beetles and larvæ and a hemipterous predator, assisted in late summer by a hymenopterous parasite, were seldom able to clear up colonies of this rapidly reproducing aphid. Another insect associated with the aphid colonies was a large black ant that attended in small numbers.

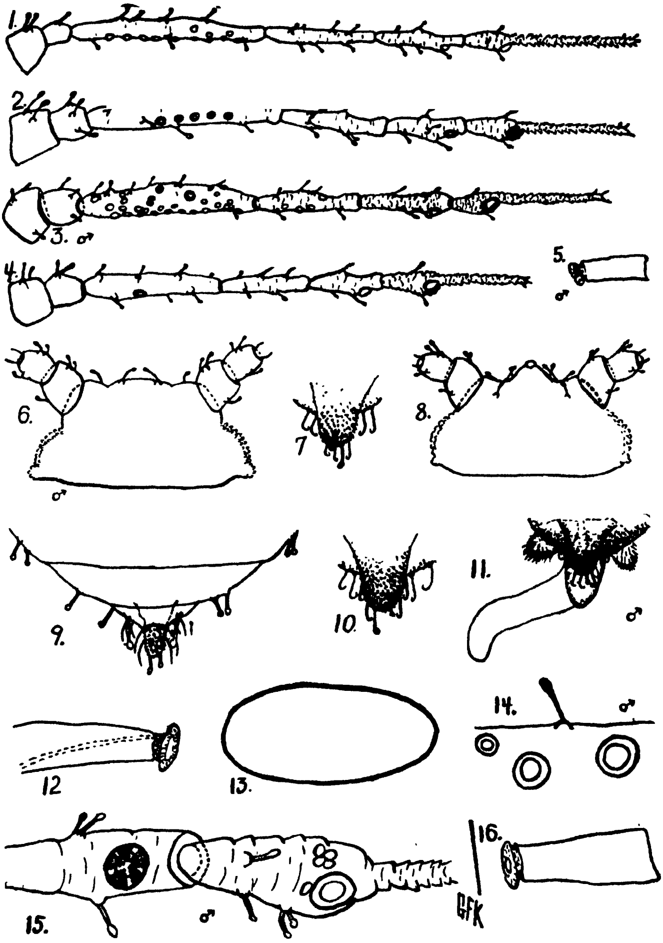

FIGURE I.

1, Antenna of alate viviparous female; 2, antenna of apterous viviparous female; 3, antenna of male; 4, antenna of oviparous female; 5, cornicle of male; 6, head of male; 7, cauda of oviparous female; 8, head of alate female; 9, posterior end of alate female; 10, cauda of apterous female; 11, posterior end of male; 12, cornicle of alate female; 13, egg; 14, portion of male antennal III much enlarged; 15, portion of antennal V and VI of male, much enlarged; 16, cornicle of oviparous female.

Alate vivipara.—Size 2.5 to 2.8 mm. long; sensilla over body and appendages prominent and spinelike, most of which are enlarged at the tip; abdomen rather broad; antennal tubercles moderately prominent; antennæ rather short and black; antennal III, 0.35 to 0.42 mm. with nine to thirteen wide-margined secondary sensoria in irregular row or sometimes rather scattered; IV, 0.21 to 0.25 mm. with 0 to 1 sensorium; V, 0.15 to 0.19 mm.; VI, 0.35 (0.1+0.25) mm.; legs rather short; wing venation not reduced, veins prominent, brownish-black; body yellowish-green and shiny as though moist; lateral tubercles lacking; cornicles large, prominent, 0.33 mm. long, cylindrical, black, with pronounced constriction before broad flange; cauda cone-shaped, with several pointed and two globate sensilla.

Apterous vivipara.—Length 2.2 to 2.8 mm.; width of well-arched abdomen 1.16 mm.; body and appendages armed mostly with spine-like sensilla, usually enlarged at tip; rostrum reaches beyond second coxa; antennal tubercles moderately prominent; antennæ yellowish-green to blackish; segments III, 0.37 mm., with two to six secondary sensoria in a row; IV, 0.25 mm.; V, 0.17 mm.; VI, 0.31 (0.1 + 0.21 mm.); body yellowish-green, shiny, as though moist; cornicles large, 0.41 mm. long, blackish to black, with a pronounced constriction before prominent flange; cauda cone-shaped, elongate, with two globate and several pointed sensilla.

Apterous ovipara.—Similar to apterous vivipara, but with two or three large, light-colored eggs usually showing through the wall of the well-arched abdomen; rostrum long, reaching abdomen; antennal III, 0.27 mm. with one or two sensoria: IV, 0.18 mm.; V, 0.13 mm.; VI, 0.25 (0.08 + 0.17) mm.; cornicles 0.35 mm. long, prominent, blackish but slightly smaller than in the vivipara.

Apterous male.—Length 0.82 to 1 mm., much smaller than the female; rostrum long, reaching abdomen; antennal tubercles moderately prominent; antennæ conspicuous, black; III, 0.3 mm. with seventeen to thirty scattered sensoria; IV, 0.15 mm. with 0 to 3 sensoria; V, 0.13 mm.; VI, 0.26 (0.07 + 0.19) mm.; sensoria with wide margins; hairs over body and appendages prominent and usually enlarged at tip; more active, nervous and awkward appearing than other forms; body reddish-brown to dark red with long legs mostly black; cornicles small, black, cylindrical, 0.13 mm. long with constriction before the flange; cauda conical, with usually only one globate hair at tip, besides long, pointed hairs.

Egg.—0.7 to 0.8 mm. long; whitish-yellow in body and when deposited, but later becoming greenish-yellow, bright green, blackish, and finally shining black. First eggs were observed September 20, 1926. Eggs found free or cemented to scales below flower heads and on twisted leaves.

Cotypes in the collection of the Utah Agricultural Experiment Station and in the U. S. National Museum.

NEW SPECIES OF ACINOPTERUS (HOMOPTERA, CICADELLIDÆ).*

Paul B. Lawson,
Lawrence, Kansas.

The material on which this paper is based has been accumulating for several years chiefly through the collecting of Mr. A. A. Nichol in Arizona. This southwestern region seems to be the native land for most of the members of this genus and will doubtless continue to yield new species. The writer is greatly indebted to Mr. Nichol for the fine lot of specimens sent him and wishes also to acknowledge his gratitude to Dr. E. D. Ball for the generous use of material from his collection and also to those in charge of the collections of the United States National Museum for the privilege of studying all the specimens there. Thanks are also due Miss Kathleen Doering for making the drawings.

Since this paper adds so many new species to the genus it has been thought best to present the following new key for the separation of all the species that are now to be included in the genus.

Key to Species.

A. Apex of tegmen strongly acute; costal margin straight clear to tip.
  B. Species more or less distinctly greenish.
    C. Species large, females over 6 mm. long; elytra milky-green *lactus* sp. n.
    CC. Species smaller, females less than 6 mm. long.
      D. Species usually bright green throughout; elytra usually with green veins.......................................*productus* Lawson
      DD. Species with elytra at least pale green and usually without green veins.
        E. Species distinctly green; vertex angularly produced. .*arizonanus* sp. n.
        EE. Species but slightly green; vertex more roundingly produced, *productus* var. *albidus* var. n.
  BB. Brownish or grayish species.
    C. More robust species.
      D. Darker colored species.
        E. Male plates long and narrow, parallel-margined, apices rounded; last ventral segment of female without lateral angles, *acuminatus* Van Duzee
        EE. Male plates broader and shorter, apices distinctly divergent; last ventral segment of female with distinct lateral angles, *angulatus* Lawson
      DD. Lighter colored species.
        E. Veins strongly margined with black, giving striking variegated appearance.......................................*pulchellus* sp. n.

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*Contribution from the Department of Entomology, University of Kansas.

EE. Veins not strikingly margined with black.......... *pruinosus* sp. n.
CC. More slender species.
D. Front, viewed from side, strongly convex.
E. Yellowish-white species; tip of second anal vein darkened, *inflatus* sp. n.
E. Pale buff species; tip of second anal vein not darkened. *doeringi* sp. n.
DD. Front, viewed from side, straight or but slightly convex.
E. Species not at all or but slightly marked with red.
F. Species usually over 5 mm. long.
G. Vertex strongly and roundingly produced, *productus* var. *fulvus* var. n.
GG. Vertex more angularly or less strongly produced.
H. Pale yellow species; veins with but few faint dark borders, *inornatus* (Baker)
HH. Yellow to brownish species; veins, especially apically, distinctly bordered with brown.
I. Species 5.75 mm. long or over............... *balli* sp. n.
II. Species less than 5.75 mm. long............ *catalinanus* sp. n.
FF. Species usually less than 5 mm. long.............. *parvulus* sp. n.
EE. Species strikingly suffused with red............... *aridellus* Osborn
AA. Apex of tegmen rounded; costal margin not running straight clear to tip.
B. Species brownish or grayish, not distinctly green.
C. Robust species.
D. Species large; last ventral segment of female strongly produced medially................................. *brunneus* Ball
DD. Species smaller; last ventral segment of female normally produced.
E. Species with elytra but slightly variegated.
F. Very robust species, less than 5.5 mm. long .... *latus* sp. n.
FF. Less robust species; 5.5 mm. or longer...... .. *pallidus* Lawson
EE. Species with elytra distinctly variegated. . .*viridis* var. *variegatus* Ball
CC. Rather elongate species.
D. Over 5 mm. long; elytra quite long ....*elongatus* sp. n.
DD. Less than 5 mm. long; elytra distinctly shorter.
E. Almost uniformly brownish; plates of male distinctly pointed and diverging apically......... .... *rileyi* sp. n.
EE. Greenish-yellow, elytra marked with brown; plates of male more rounded and less divergent apically............ . *bakeri* sp. n.
BB. Greenish species.
C. Species larger; plates of male tapering and distinctly divergent apically .... *viridis* Ball
CC. Species smaller; plates of male parallel-margined and but slightly divergent apically......... .... *obtutus* Lawson

Acinopterus lactus sp. n.

The largest of the greenish species. Close to *productus* but larger. Length of female 6–6.25 mm.

Vertex half longer at middle than next the eye, not quite twice as wide as long, without transverse depression. Pronotum less than twice as long as vertex, over twice as wide as long. Elytra with acutely pointed apices and with five or six cross-veins between first and second anal veins. Last ventral segment of female characteristic of genus, the lateral margins rounding to slightly notched and produced posterior margin. Pygofer bearing a few short spines and slightly exceeded by ovipositor.

Color: Pale green above and below except for brown eyes. Elytra diffused with milky-white, with few dark spots apically. Wings smoky apically. Underside pale to bright green.

Holotype, female, Sierrita Mts., Arizona, 3000–4000 ft. *Paratype*, female, Tempe, Arizona. Both types taken by Mr. A. A. Nichol. Deposited in the Snow Entomological Collection.

Acinopterus arizonanus sp. n.

A greenish species close to *lactus* but smaller and with more sharply pointed vertex. Length of female 5.6 mm.; length of male 5.4 mm.

Vertex half longer at middle than next the eye, almost twice as wide as long, without transverse depression. Pronotum scarcely twice as long as vertex, over twice as wide as long. Elytra with acutely pointed apices and with one to eight cross-veins between first and second anal veins. Genitalia of female characteristic of the genus. Male plates a little over half the length of pygofer, nearly parallel-margined, apices rounded and slightly diverging.

Color: Varying from pale green above and below to bright green except for elytra. Eyes reddish. Elytra, especially in male, with brown-bordered veins and with small dark spots apically. Wings smoky apically and with dark veins. Underside pale to bright green.

Holotype, female, St. Catalina Mts., Arizona, 2700 ft. *Allotype*, male, Tucson, Arizona. Both types taken by Mr. A. A. Nichol. Deposited in the Snow Entomological Collection.

Acinopterus pulchellus sp. n.

A robust gray species with veins almost uniformly bordered with black. Length 5.5 mm.

Vertex half longer at middle than next the eye, twice as wide as long, rather broadly rounded with front, with a slight transverse depression. Pronotum less than twice as long as vertex, over twice as wide as long. Elytra short and broad, apices moderately acute, claval area with more cross-veins than in any other species of the genus. Last ventral segment of female of normal shape, the posterior margin slightly sinuated. Plates of male nearly two-thirds the length of pygofer, distinctly tapering from broad bases to rather definitely acute and divergent apices.

Color: Olive-gray. Vertex with two black spots at base running parallel to inner margin of eyes. Pronotum with several black spots on anterior third parallel to anterior margin, and with large dark band of scutellum showing through posterior third. Scutellum with basal angles dark. Elytra with all veins strongly bordered with black, the cells along the elytral suture appearing lighter than the others. Eyes dark brown. Frontal arcs black. Base and spot on disc of clypeus black. Dorsum of abdomen and veins of wing black. Underside mostly greenish-gray.

Holotype, female; *allotype*, male. Both from Tempe, Arizona. Taken by Mr. A. A. Nichol. Deposited in the Snow Entomological Collection.

Acinopterus pruinosus sp. n.

A pale brownish-yellow species close to *inornatus* but more robust, Length 6–6.25 mm.

Vertex half longer at middle than next the eye, slightly over twice as wide as long, without distinct transverse depression, anterior margin distinctly but not sharply angulate. Pronotum scarcely twice as long as vertex, over twice as wide as long. Elytra with strongly acute apices and with several cross-veins between first and second anal veins. Female genitalia characteristic of the genus.

Color: Pale brownish-yellow except for reddish eyes and few darker emarginations of veins, especially in apical half. Entire upper surface more or less distinctly pruinose. Underside yellowish, sometimes tinged with red.

Holotype and two *paratypes*, females, from the Santa Rita Mts., Arizona, 5000–8000 ft. Taken by F. H. Snow. Holotype and one paratype in Snow Entomological Collection; other paratype in collection of Dr. E. D. Ball.

Acinopterus inflatus sp. n.

A yellowish-white species with strongly convex front. Length 4.8–5.4 mm.

Vertex nearly twice as long at middle as next the eye, nearly twice as wide as long, rounding broadly with inflated front. Pronotum less than twice as long as vertex, over twice as wide as long. Elytra with moderately acute apices and with several cross-veins between first and second anal veins. Female genitalia characteristic of genus. Male plates over half the length of pygofer, nearly parallel-margined, apices moderately rounded.

Color: Pale yellowish-white with veins in apical half of elytra bordered with black and with second anal veins tipped with black. Male sometimes darker with greenish cast and elytra fairly well spotted with brown. Eyes reddish. Underside yellowish or pale green. Veins of wings black.

Holotype, female; *allotype*, male; *paratypes*, two females and one male. All taken at Tucson, Arizona, by Mr. A. A. Nichol. Two paratypes in collection of Mr. Nichol; other types in Snow Entomological Collection.

Acinopterus doeringi sp. n.

A pale brown species, close to *inflatus*. Length 5.1 mm.

Vertex less than twice as long at middle as next the eye, about twice as wide as long, without transverse depression, broadly rounding with strongly convex front. Pronotum less than twice as long as vertex over twice as wide as long. Elytra with apices fairly acute and with several rather indistinct cross-veins between first and second anal veins. Genitalia of female characteristic of the genus.

Color: Pale brown and more or less pruinose above. Orange band between ocelli. Eyes dark brown. Costal plaques white and apical cells of elytra darkened. Underside slightly darker and with faint reddish tinge.

Holotype, female, Tucson, Arizona. Taken by Mr. A. A. Nichol. Deposited in Snow Entomological Collection.

Acinopterus productus var. **albidus** var. n.

Form and size of *productus.*

Color: Greenish-white above and below with just a suggestion of the green. Eyes reddish. Elytra pale except for the dark spots in the apical cells.

Holotype, male; *allotype*, female; *paratype*, male. All from Tucson, Arizona. Paratype taken by Mr. R. B. Streets; other types by Mr. A. A. Nichol. Paratype in Mr. Nichol's collection; other types in Snow Entomological Collection.

Acinopterus productus var. **fulvus** var. n.

Form and size of *productus.*

Color: Practically uniformly fulvous above and below except for reddish eyes and darker margins of tips of claval veins and some of the veins in apical portion of elytra.

Holotype, male, taken by Mr. R. B. Streets, and *allotype*, female, taken by Mr. A. A. Nichol, both from Tucson, Arizona. Types deposited in Snow Entomological Collection.

Acinopterus balli sp. n.

Varying from pale yellow to pale brown. Close to *inornatus* but with male plates wider and more pointed apically, with more cross veins between first and second anal veins and with elytra much more definitely marked with dark brown. Length 5.75–6.1 mm.

Vertex varying from half longer to nearly twice as long at middle as next the eye, about twice as wide as long, anterior margin usually distinctly angulate, with faint transverse depression. Pronotum nearly twice as long as vertex, over twice as wide as long. Elytra long and acutely pointed, with four or more cross-veins between first and second anal veins. Genitalia of female characteristic of the genus. Plates of male fairly broad, nearly parallel-margined, apices well rounded and not divergent.

Color: Pale yellow to brown. Elytra more or less marked with brown, especially apically, veins appearing distinct and lighter because frequently bordered with brown. Underside sometimes tinged with red.

Holotype, male, taken by Mr. R. B. Streets, and *allotype*, female, taken by Mr. A. A. Nichol, both from Tucson, Arizona. Types deposited in Snow Entomological Collection.

Acinopterus catalinanus sp. n.

A rather slender, brown species, close to *aridellus*, but larger. Length 5.1–5.3 mm.

Vertex half longer at middle than next the eye, scarcely twice as wide as long, with faint transverse depression, anterior margin distinctly angulate. Pronotum nearly twice as long as vertex, two and one-half times as wide as long. Elytra with fairly acute apices and four or more cross-veins between first and second anal veins. Male plates about two-thirds length of pygofer, nearly parallel-margined, apices well rounded and but slightly divergent.

Color: Almost uniform light brown except for darker borderings of elytral veins, especially near the apex. In one specimen some of the veins lightly streaked with red. Wings smoky apically and with dark veins.

Holotype and *paratype*, both males (latter with abdomen lacking), taken by Mr. E. L. Dickerson in the Sabino Canyon, St. Catalina Mts., Arizona. Types deposited in the Snow Entomological Collection.

Acinopterus parvulus sp. n.

The smallest member of the genus, elongate, greenish-brown. Length 4.7 mm.

Vertex nearly twice as long at middle as next the eye, nearly twice as wide as long, with faint transverse depression, anterior margin sharply angulate. Pronotum half longer than vertex, over twice as wide as long. Elytra unusually long and slender, apices sharply acute, with several claval cross-veins. Male plates a little over half the length of pygofer, broader at base, tapering to slightly divergent and narrower apices.

Color: Greenish-brown, the pale veins of elytra nearly all bordered with darker brown. Thorax and dorsum of abdomen black. Wings smoky apically and with black veins. Underside mostly dusky green.

Holotype, male, taken at Ontario, Calif., By Dr. E. D. Ball. Deposited in Dr. Ball's collection.

Acinopterus latus sp. n.

A very robust yellowish-brown species, close to *pallidus* but with much shorter elytra and with vertex and last ventral segment of female more produced medially. Length 5.25 mm.

Vertex half longer at middle than next the eye, over twice as wide as long, with distinct transverse depression, anterior margin not distinctly angulate and broadly rounding with front. Pronotum nearly twice as long as vertex and nearly two and one-half times as wide as long. Elytra short and very broadly rounded apically, with four or five cross-veins between first and second anal veins. Last ventral segment of female produced a little more strongly medially than in most members of the genus; pygofer normal.

Color: Uniform yellowish-brown except for small darker brown spots scattered over elytra.

Holotype, female, labelled "Dacota, Rothemer." Deposited in the United States National Museum.

Acinopterus elongatus sp. n.

A long yellowish-brown species, close to *variegatus* but much more slender. Length 5.25 mm.

Vertex half longer at middle than next the eye, twice as wide as long, broadly rounding with front, transverse depression very faint. Pronotum about twice as long as vertex, over twice as wide as long. Elytra long, apices rounded though not as much as in *latus*, without cross-veins in claval area. Plates of male moderately broad at base, tapering to fairly rounded apices, a little over half the length of the pygofer.

Color: Almost uniform yellowish-brown. Elytra with dark brown spots particularly at tips of second and third anal veins and along veins in apical half, some of the veins streaked with red.

Holotype, male, taken by Coquillet at Los Angeles, Calif. Deposited in the United States National Museum.

Acinopterus rileyi sp. n.

A small brown species, as short as *parvulus* but more robust. Length 4.7 mm.

Vertex half longer at middle than next the eye, half wider than long, broadly rounding with front, without transverse depression. Pronotum half longer than vertex, over twice as wide as long. Elytra short, apices distinctly rounded, with one or two very faint cross-veins on clavus. Plates of male long, broad at base and strongly narrowed to the rather acute and distinctly divergent apices.

Color: Pale brown except for darker borders of elytral veins, these more heavily bordered apically. Wings smoky apically, the veins black. Legs and pygofer tinged with pinkish.

Holotype, male, taken by C. V. Riley in Texas. Deposited in the United States National Museum.

Acinopterus bakeri sp. n.

A slender greenish-gray species, close to *variegatus* but more slender and vertex narrower and more elongate. Length 4.7 mm.

Vertex twice as long at middle as next the eye, twice as wide as long, anterior margin angulate, transverse depression faint. Pronotum less than twice the length of vertex, over twice as wide as long. Elytra moderately long, apices rounded just enough to place the species in the group lacking the acute apices, claval area with several cross-veins. Plates of male quite long, two-thirds the length of pygofer, tapering from broad base for half their length, then running parallel to the well rounded apices.

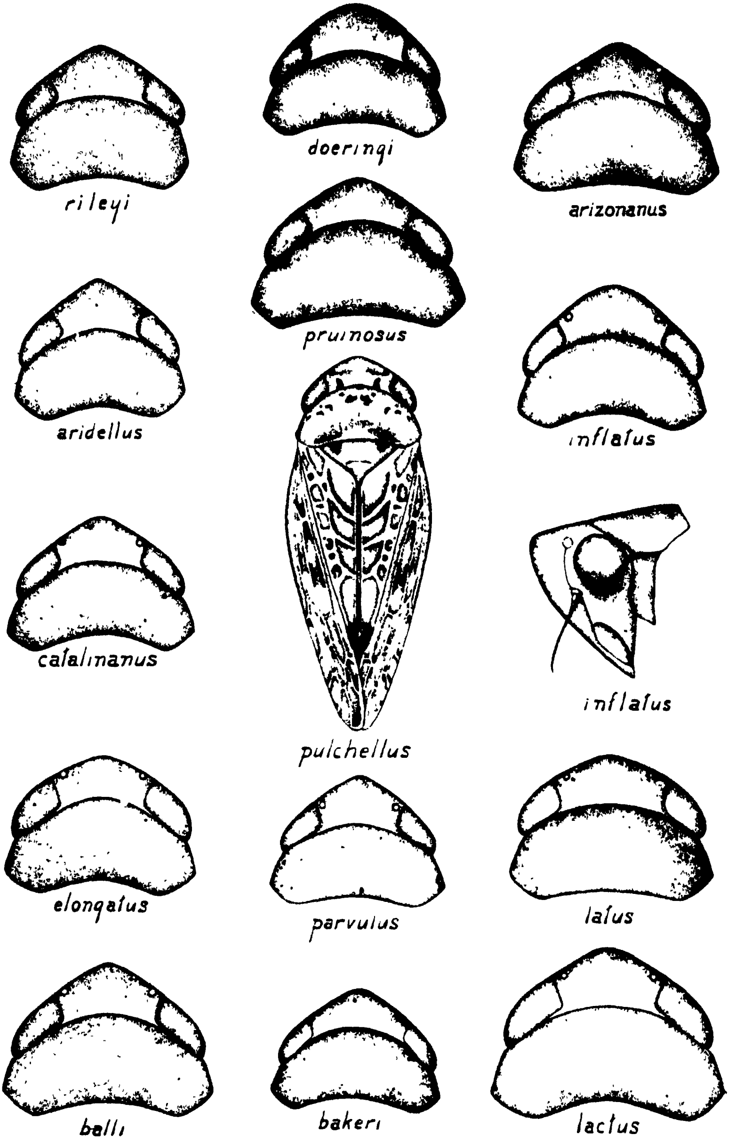
Color: Gray. Head and vertex with greenish tinge and most of the elytral veins, especially on the corium, bordered with dark brown. Eyes brownish. Underside greenish-gray.

Holotype, male, taken by C. F. Baker in Arizona. Deposited in the United States National Museum.

The external genitalia in this genus are sometimes clearly specific as in *brunneus* and *angulatus*. More often, however, the differences in the genitalia, both of male and female, are very minute, and can be seen only when the specimens of the several species are compared side by side. In most cases, therefore, the genitalia in the above new species have not been exactly described but have been spoken of as characteristic of the genus. Greater differences are manifest in the male plates than in the last ventral segment of the female though even here they are very difficult to describe because of their slightness. There seems to be no question, however, that at least very slight specific differences practically always exist.

In his paper on this genus (Kansas Univ. Sci. Bul., XIV, p. 122, 1922), the writer expressed his doubt about the reference of a number of specimens to *A. inornatus* (Baker). Further comparisons between the type and most of these specimens reveal distinct differences, so that the type specimen seems to stand alone. It is particularly different from all the specimens formerly referred to this species in its paler color and the comparative indistinctness of the cross-veins of the claval area.

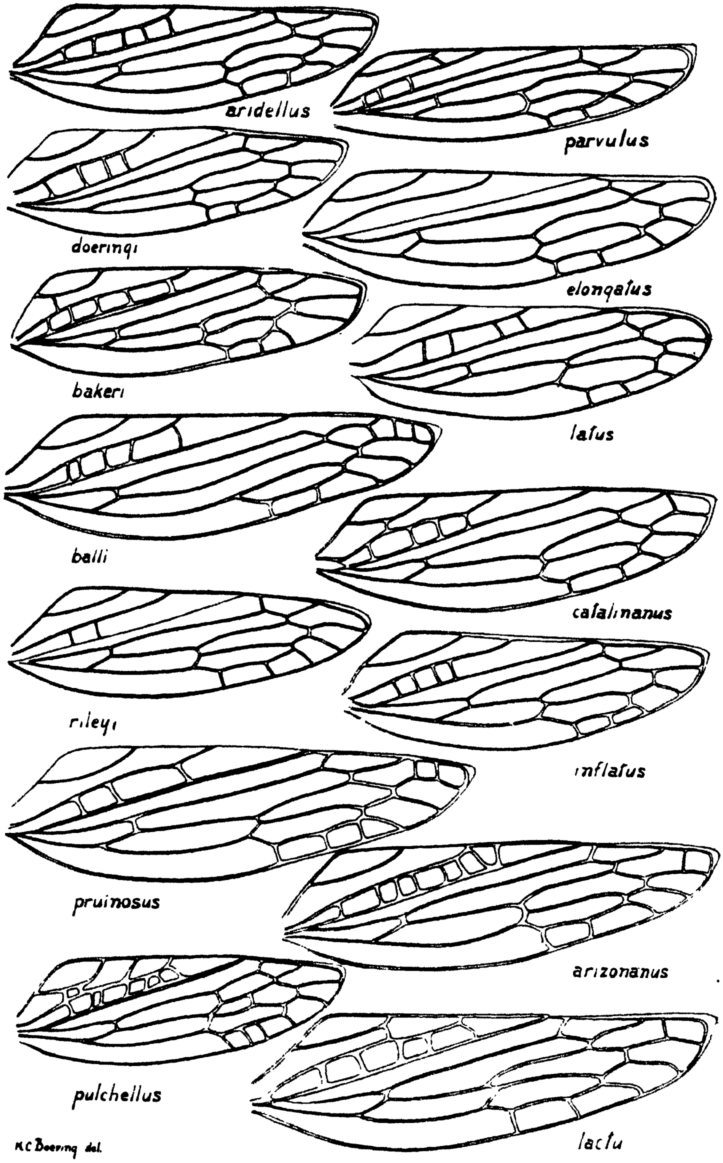
A. angulatus Lawson seems to be a tropical or subtropical species that has extended its range into the southern states. Through the courtesy of Mr. Harold Morrison the writer has identified specimens of this species from Mexico, Jamaica, Republic of Domingo and Cuba. Also through the courtesy of Dr. Hugo Kahl he has been able to identify specimens of this species from Brazil and Colombia. These specimens were formerly referred to *A. acuminatus*, but the latter clearly seems to be a North American species and all tropical and subtropical references to this species should be changed to *angulatus*.



K.C. Doering del.

Head and prothorax of species of *Acinopterus.*

Paul B. Lawson



Venation of species of *Acinopterus*.

Paul B. Lawson

ON THE SEASONAL MIGRATIONS OF DIONE VANILLÆ IN KANSAS.

VANCE RANDOLPH.

Dione vanillæ is a common butterfly in South and Central America, in Mexico, and in the southern part of the United States, from southern Virginia southward to Arizona and California.[1] Scudder[2] reported it as rare north of the 35th parallel, but I have collected hundreds of specimens in Kansas, and in the Ozark Mountains of Missouri and Arkansas. A few strays have been taken in West Virginia,[3] New Jersey and Pennsylvania,[4] but *Vanillæ* is really a tropical butterfly. In the central states the northern limit of its usual range falls somewhere in central or northern Kansas; it is fairly common in the southern portion of the state, but is rarely taken more than 150 miles north of the Oklahoma border.

In the tropics, of course, *Vanillæ* breeds continuously, and this is also the case in California[5] and in Florida, although in the latter state the butterflies are much less abundant during the winter months. In the northern part of its range, however, *Vanillæ* appears only for two or three months in the year, and nobody knows where or in what stage of development it passes the winter.[6] My own observations of this butterfly were made near Pittsburg, in southeastern Kansas, in the period between 1915 and 1925. For ten summers I collected Lepidoptera in this region, and reared hundreds of specimens of *Vanillæ* under all sorts of conditions,[7] but was never able to determine how these butterflies managed to survive the Kansas winter.

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[1] Holland, W. J. *The Butterfly Book*, New York, 1898, p. 97.

[2] Scudder, Samuel Hubbard. *The Butterflies of the Eastern United States and Canada*, Cambridge, Mass., 1889, Vol. III, pp. 1811-1819.

[3] Edwards, W. H. Description of the Preparatory Stages of Agraulis vanillæ, Linnaeus, *Canadian Entomologist*, Vol. XII, 1880, p. 125.

[4] Maynard, C. J. *Manual of North American Butterflies*, New York, 1891, p. 50.

[5] Wright, William Greenwood. *West Coast Butterflies*, San Bernardino, 1905.

[6] Scudder, Samuel Hubbard. *The Butterflies of the Eastern United States and Canada*, Cambridge, Mass., 1889, Vol. III, pp. 1811-1819.

[7] Randolph, Vance. Life History and Habits of Dione vanillæ, *Transactions Kansas Academy of Science*, Vol. XXX, 1919-1921, pp. 351-362.

The butterfly itself never appears in Kansas until about August 1st, and I have never taken one later than the 28th of November. This late appearance, and the fact that the first specimens to appear are apparently fresh and in good condition, does not lend any particular support to the view that *Vanillæ* hibernates as an imago. A ten-year search has failed to locate a single living chrysalid later than November 21st, and since the butterfly usually emerges only seven or eight days after pupation, we may be fairly certain that *Vanillæ* does not sleep through the cold weather in the pupa state. As to the caterpillars, those which I have reared always either pupated or died before November 15th, and a most painstaking examination of the leaves and dirt near the food-plant has not uncovered a single caterpillar in the winter time. There is no evidence whatever that *Vanillæ* passes the winter as a caterpillar. The eggs are deposited on the green leaves of the food-plant, and the incubation period is only 6 or 7 days. I have never found eggs earlier than July 27th or later than September 28th, and there is no reason to suppose that they ever live through the first frost.

Thinking to settle this question once for all, in the summer of 1921 I transplanted a *Passiflora* vine into a large pot, and enclosed the whole thing in a fine-meshed wire cage. Into this cage I put about 500 living specimens of *Vanillæ*—eggs, caterpillars, chrysalids and butterflies. The first cool weather apparently killed the last of these, but on December 25th I opened the cage and examined its contents very carefully, sifting every bit of the dirt through a fine wire screen, and examining it with a powerful reading lens. Not a single living specimen did I find—no egg, no caterpillar, no chrysalid, no hibernating imago. The following year I repeated the experiment, except that this time I did not open the cage at Christmas, but allowed it to remain locked until August 30, 1923. No sign of life appeared—not one *Vanillæ* had survived the Kansas winter.

If *Vanillæ* does not winter in Kansas, we may assume that each year a few of the butterflies drift up from the South, breed as long as the Summer lasts, and are destroyed with all their progeny by the first frosty weather. I am told that *Vanillæ* appears in southern Arkansas and Oklahoma about the middle of June, but have never seen a specimen myself earlier than July 20th. It certainly flies earlier than this in Texas, since Edwards[8] reports eggs deposited in Dallas on June 19th. It has been suggested that these butterflies hibernate in some of the Southern States; it may be, however, that they do not hibernate anywhere, but follow the warm weather north from Mexico, where they are said to breed the year round. It is not necessary to suppose that an individual butterfly flies from Mexico to southern Kansas, but it may be that a few individuals drift north for several hundred miles, and deposit the last of their eggs at the end of the journey. Some 25 days[9] later, when the butterflies of this brood emerge, the season is still farther advanced, and if a few of these also wander northward it might be possible for the third or fourth generation to arrive in Kansas by the early part of August. It would certainly be interesting to know the precise dates on which *Vanillæ* first appears at a series of points between southern Kansas and the northernmost region in which it breeds continuously. This information, unfortunately, is not available at present.

The only positive conclusion which may be drawn from my observations and experiments is this: *Dione vanillæ* does not spend the winter in Kansas. My remarks about migration are highly speculative, of course. It is very difficult to find out anything definite about the migration of butterflies, and for this reason, it seems to me, every scrap of information on the subject should be carefully preserved for the use of future investigators.

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[8] Edwards, W. H. Description of Preparatory Stages of Agraulis vanillæ, Linnaeus, *Canadian Entomologist*, Vol. XII, 1880, p. 125.

[9] Edwards, W. H. Description of Preparatory Stages of Agraulis vanillæ, Linnaeus. *Canadian Entomologist*, Vol. XII, 1880, p. 125.

THE HIPPOBOSCID FLY, ORNITHOMYIA AVICULARIA LINNAEUS, AS A CARRIER OF MALLOPHAGA.

H. E. Ewing,
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It is of fundamental importance in the study of questions relating to the distribution and phylogeny of parasites to know of those agencies or conditions which break down natural barriers to their spread from host individual to host individual and from host species to host species. In the case of host species of solitary habits their ectoparasites are thought to be marooned on such species much in the manner of inhabitants of an island. In general it may be stated, as held by Kellogg (1915), that the lice of such species have, through association, followed the same road in their phylogenetic development as their hosts; or, in other words, that hosts and parasites have had a parallel phylogeny.

In those striking examples, however, where we find closely related ectoparasitic species infesting diverse host groups the question arises, by what agencies did their ancestors get from the host species of one group to those of another?

As far back as 1895 Sharp suggested that "possibly Mallophaga may be transferred from one bird to another by means of the parasitic two-winged flies that infest birds." He had previously recorded (Sharp, 1890) a case in which a bird-fly had been captured with several Mallophaga adhering to it.

Some years later Jacobson (Jacobson, 1911) reported the collecting of a Hippoboscid (*Ornithoeca pusilla*) which had a Mallophagan "clasped between the legs." This bird-fly had escaped from a bird, *Eucichla cyanura*, immediately after Jacobson had shot it.

After reflecting on the possible significance of this observation Jacobson states (1911, p. 169) that, "it may be presumed that the habit of the Mallophaga to use Hippoboscidæ as conveyance, will be found to be quite a common occurrence with these insects, and more attention should be paid in the future to this point." Indeed Jacobson's presumption has been fully justified, for up to the present no less than eleven authentic cases have been recorded of Hippoboscids carrying Mallophaga or at least of their being found with Mallophaga attached to them.

A short summary of most of these cases was given by McAtee (1922). After summarizing eight cases McAtee remarks that it is rather surprising that so many of the records should be for the Hippoboscid genus *Ornithomyia*. The present writer would also like to add, after reporting two new cases for this genus, that it is even more surprising that so many of the records are for a single species of *Ornithomyia*, *O. avicularia* Linn.

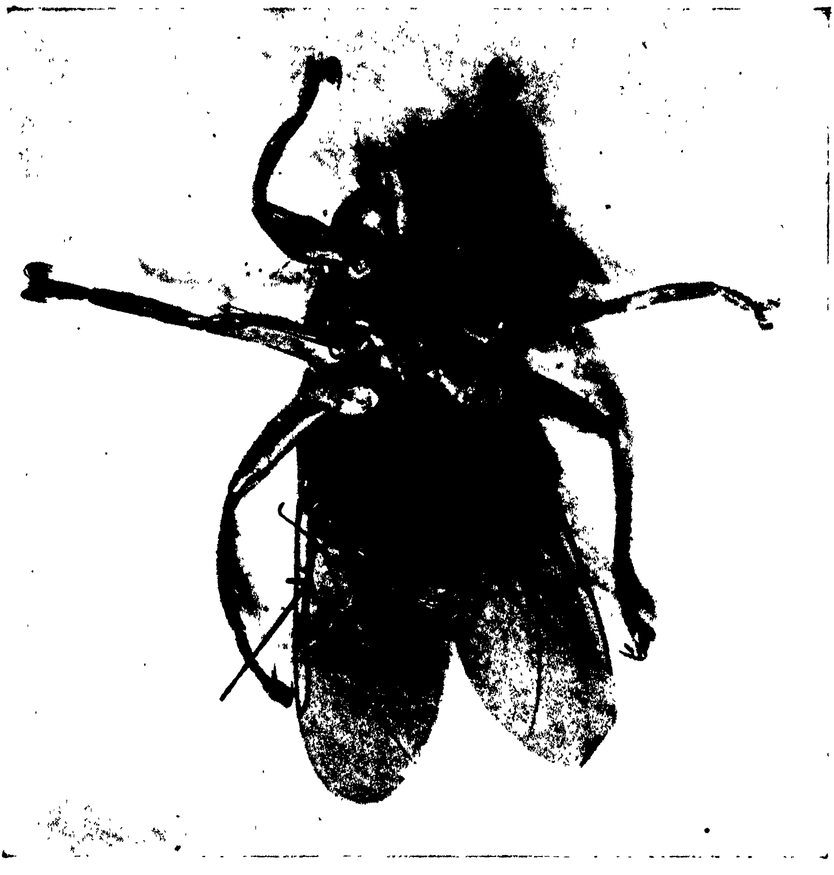

FIG. 1. *Ornithomyia avicularia*, greatly enlarged, showing a biting louse, *Degeeriella interposita* (Kellogg), attached to the right posterior aspect of the abdomen. (Photo by Pratt).

NEW RECORDS.

Dr. J. M. Aldrich recently (1926) called my attention to two specimens of *Orithomyia avicularia* that were found to harbor biting lice. One of them which had been collected by R. Boulton from a song sparrow, *Melospiza melodia melodia*, at Gates Mills, Ohio, June 30, 1926, had two specimens of *Degeeriella interposita* (Kellogg), an adult male and female, attached to the postero-lateral aspect of the abdomen. These lice were so attached that their bodies produced a perfect symmetry with that of the host, each having the head forward and the body extending backward along the side of that of the fly. The body wall around one of these lice was dissected away, the remaining piece being held in the mandibles of the louse. When this louse was mounted on a microscope slide it was found that the Mallophagan had bitten into the body wall with the mandibles. In doing so it had clasped loosely a small seta, but this fact appears to have been incidental. It was especially interestint to ascertain the exact method of attachment, as this point had been overlooked in most of the cases previously reported.

The other fly (see Figure) had been taken by R. Boulton from a catbird, *Dumetella carolinensis*, at Gates Mills, Ohio, July 29, 1926, and had one specimen of *Degecriella interposita* (Kellogg) attached in exactly the same way that the other two were attached.

A tabular summary of the nine cases involving the bird-fly *Ornithomyia avicularia* is given on next page.

Ornithomyia avicularia Linnaeus Chiefly Concerned.

After reviewing the known records of Hippoboscids carrying Mallophaga it is found that in eight of the eleven cases *Ornithomyia avicularia* is mentioned as the transporting species and in the remaining cases one named host, *Ornithomyia anchineura* Speiser, should, according to Ferris and Cole (1922), be considered as a synonym of *O. avicularia*. Of the two other cases, in one instance the fly was determined as an *Ornithomyia* but the species was not given. It develops then that in only a single instance, that reported by Jacobson (1911) was the bird fly known definitely not to be *O. avicularia*. When one reflects that there are at least seventeeen genera of bird-infesting

Hippoboscidæ and about three times as many species he is convinced that unusual conditions prevail for the attachment of biting lice to this one fly species.

TABULATION OF RECORDS OF MALLOPHAGAN INFESTATION OF ORNITHOMYIA AVICULARIA LINNEUS

Date	By Whom Reported	Bird Host	Country	Mallophagan Species	Number of Attached Lice	Remarks
1890	D. Sharp	Not reported	England	Not determined	"Several specimens"	"Firmly adhering apparently by the mandibles."
1903	R. Forsius	*Tetrao tetrix*	Finland	*Degeeriella quadratula* (N.)	1	Fastened at base of wing.
1908	R. Forsius	*Corvus cornix*	Finland	*Degeeriella uncinosa* (N.)	2	One on hind tibia and one on abdomen.
1910	B. Wanach	Probably *Planesticus merula merula*	Germany	*Philopterus* sp.	1	On abdomen.
1919	C. W. Johnson	*Perisoreus barbouri*	Quebec, Canada	Not determined	2	Attached one on each side of abdomen.
1920	W. L. McAtee	Not known	Saskatchewan, Canada	*Degeeriella rotundata* (O.)	1	Attached by mandibles to upper surface of abdomen.
1920	W. L. McAtee	*Corvus brachyrhyncos hesperis*	Oregon, United States	*Degeeriella rotundata* (O.)	1	Attached by mandibles to upper surface of abdomen.
1926	This paper	*Melospiza melodia melodia*	Ohio, United States	*Degeeriella interposita* (K.)	2	Attached to body-wall of abdomen by mandibles.
1926	This paper	*Dumetella carolinensis*	Ohio, United States	*Degeeriella interposita* (K.)	1	Attached to body-wall of abdomen by mandibles

One Mallophagan Genus Chiefly Involved.

While one Hippoboscid fly is almost the sole carrier of the Mallophaga, several species of lice are involved, yet it is remarkable that out of the seven cases where the lice were determined to genus or species, six of them should prove to belong to the single genus *Degeeriella*. And in the other case, the species belongs to the genus *Philopterus*, a genus never separated from *Degeeriella* by any clear cut generic character.

The Bird Host Species.

The bird hosts for all cases where *Ornithomyi aavicularia* is concerned are as follows, in so far as known:

European blackbird, *Planesticus merula merula.*
European black grouse, *Tetrao tetrix.*
European hooded-crow, *Corvus cornix.*
Canadian jay, *Perisoreus barbouri.*
Western crow, *Corvus brachyrhynchos hesperis.*
Song sparrow, *Melospiza melodia melodia.*
Catbird, *Dumetella carolinensis.*

Habits of Hippoboscid Favorable for a Wide Distribution of the Lice Carried.

It is important to note that in no two cases reported of *Ornithomyia avicularia* carrying lice has the bird host been of the same species. Not only this, but such unrelated birds as the European blackbird, a thrush, the European black grouse, the American song sparrow and the hooded crow are included. The habits of this fly in visiting bird species of such a wide range, coupled with its demonstrated habit of frequently carrying different louse species, indicates that it is an agent of great importance in the transfer of lice from bird species to bird species as it changes hosts.

Why do the Lice Concentrate Chiefly on a Single Bird-Fly Species for Attachment?

It is certainly surprising to find that nearly all the records of attachment have to do with a single Hippoboscid species, *Ornithomyia avicularia*, when we further reflect that there are no records for such a common bird-fly as *Lynchia americana* (Leach), a species more commonly collected than *O. avicularia.*

The conclusion is almost forced upon us that there must be something in the habits or nature of *O. avicularia* that causes the lice to attach to it. Just what this is is only a matter of conjecture. The following suggestions in the form of questions are given:

1. Could the lice be attached to the bird-flies for reasons other than transportation?

2. Are the lice attempting to obtain some of the blood the flies have imbibed from their bird hosts? It has been shown that some bird lice will occasionally eat blood (dried or liquid?).

3. Do the lice attach to the flies because the latter have temporarily become warmed by contact with the skin of the bird host?

4. Could the bird-fly give off any odor or secretion that is attractive to the lice?

Before closing it should be noted that in one instance the lice were found on flies that had flown from the freshly killed bird; hence they had attached themselves to the dipteron before the body of the bird host had become cool. Mallophaga usually leave the body of the dead host only after it has become cold, and at such times will spread to surrounding objects of almost any kind.

Direct observations on parasitized birds under controlled conditions would appear to be the next step toward the solution of these and other questions in regard to the relationships of *Ornithomyia avicularia* to its bird hosts and to its transported lice.

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NOTES ON THE BIOLOGY AND HABITS OF THE PERUVIAN COTTON SQUARE WEEVIL (ANTHONOMUS VESTITUS BOHM).

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During a brief visit to the central coastal cotton growing valleys of Peru in February and March, 1926, the writer had opportunity to make some further observations on the biology and habits of the Peruvian cotton square weevil, which is a rather important cotton pest in that country and might possibly some time be introduced into the cotton belt of the United States.

Those who are familiar with the biology of the Mexican cotton boll weevil (*Anthonomus grandis*—Bohm) will be struck with the many points of close resemblance in the development and activity of these two species.

The first known specimens of the Peruvian species were collected from the Island of Puna off the coast of Ecuador, presumably, between 1851 and 1853. The species was described by Boheman in 1859, but with no information as to its possible host relationships or possible economic importance. Apparently the next record regarding the species came through the work of Dr. C. H. T. Townsend in 1910 while he was working in the northern portion of Peru. Dr. Townsend was actively connected with early investigations on the Mexican cotton boll weevil and was, therefore, unusually well prepared to appreciate the importance of this Peruvian weevil. At that time, he sent to the United States National Museum some 68 specimens, mostly bred from cotton squares taken in the Chira River Valley in the extreme northern part of Peru and only about 2° latitude south of the location of the original specimen. From these specimens Dr. W. D. Pierce redescribed the species in the proceedings of the United States National Museum Volume 42, pages 156 to 157. Dr. Townsend published an article on this species in 1911 in the Journal of Economic Entomology, Volume 4, No. 2, pages 241-248.

The observations given herewith were made in the valley of the Canete River located at 13° south latitude, or nearly 600 miles further south than the locality in which Dr. Townsend had worked. Upon examining specimens taken in this more southern territory, Dr. Townsend declared that they were identical with those taken by him fifteen years earlier in Northern Peru. He expressed the view that the species would be found in all Peruvian cotton growing valleys, and stated that he had not found it in Brazilian cotton growing areas.

In the Canete Valley the species was found to be of common occurrence in practically all fields, being active from January—at the beginning of their squaring season—to the end of the growing season and frequently causing rather serious damage. The Peruvian square weevil appears to attack by preference squares that are less than one-half inch in diameter and by far the greater portion of their work appears to be in squares only about one-quarter inch in diameter. Very little feeding or oviposition occurs in even the smallest bolls. The reason for this selection of small squares appears to be found in the fact that the snout of this small species, which is from 1.2 to 1.7 mm. long, is too short to penetrate through the floral envelope and enable them to feed upon the pollen sacs in squares that are more than seven-sixteenths inch in diameter. The species shows the same dependence upon pollen as food necessary for normal egg production as does the Mexican cotton boll weevil. The feeding period between the emergence and the deposition of their first eggs appears to depend largely upon their ability to secure this immature pollen source of food. Food material passes through the elementary canal in from 12 to 13 hours; and the period of preoviposition feeding varied from slightly more than 24 hours where the female had access to a cut-open square to 6 days where they had difficulty in securing pollen.

The adults of this species are difficult to locate in the field. They are very small, ranging from about 2.5 to 4 mm. in length and are of a light tan color, which renders them very inconspicuous. Furthermore they are extremely shy, run rapidly and drop or take flight far more readily than does the Mexican cotton boll weevil. During the examination of many thousands of squares and the collection of large numbers of weevil-infested squares from the stalks, only three adults were absolutely observed in the field. There was no difficulty, however, in locating the squares attacked by these weevils. The infested squares flare widely and fall to the ground more quickly after oviposition occurs than do those attacked by the boll weevil. The feeding habits are in general very similar to those of the boll weevil, except that the majority of feeding punctures are made by both males and females through the thinner, more tender areas just above the edge of the sepals rather than through the thicker basal portion of the square. Among the 50 weevils of both sexes handled in the Laboratory, an average of 3 feeding punctures per day was made.

Egg deposition normally occurs in a somewhat different location from that chosen by the boll weevil. The eggs are placed almost invariably in the upper part of the constricted basal portion of the square, the egg resting in the base of the petal rather than in the surface of the pollen sac, as is the case with the boll weevil. The frequent occurrence of two larvæ, pupæ or adults per square indicates clearly that on account of its smaller size this species is not nearly as particular in restricting its egg deposition as is the boll weevil. The egg punctures do not always show clearly the mucus and pollen particles closing the opening to the puncture, and in the laboratory it was noticed that eggs were deposited frequently within a feeding puncture. In the field proliferation occurs more quickly with the egg in the base of a petal than it does with the boll weevil, where the egg is placed in a pollen sac. The "wart" is not clearly defined, but the swelling due to the proliferation causes a distinct asymetrical bulge, on that side of the base of the square and just above the point of puncture, which is very characteristic of the work of this species. On hatching the young larva feeds for the first day or two in this proliferous mass before it works its way up through it and into the pollen sacs where its later feeding occurs. The infested squares appear to fall to the ground as a rule in 5 or 6 days instead of the 10 days usually required with the boll weevil. Therefore, most of the development of the larva occurs after the square has fallen to the ground. As many as 25 infested squares were picked from a single plant and were evidently the work of one female. In the laboratory only from 3 to 5 eggs per day were obtained per female.

Our records upon the time required for development for each stage were not sufficiently numerous to be considered fully accurate; but the following periods were shown in the cases observed at an average temperature of 79° Farenheit:

Egg period, 66 to 72 hours.
Larval period, 8 to 9 days.
Pupal period, 3 to 6 days.
Unemerged adult period, 2 to 3 days.
Total development from oviposition to emergence of adults, 15 to 20 days, or practically the same period as that for the Mexican cotton boll weevil.

It was impossible to determine the average length of adult active life. Many weevils of both sexes died under laboratory conditions during the first week; and the work was closed at the end of the second week while many more of the weevils were still active.

The sexes are distinguished upon practically the same characters as those used with the Mexican cotton boll weevil. The male's snout is distinctly shorter, thicker and rougher than is that of the female. The males average slightly smaller than females in size, but the variation of size in each sex is considerable. The pygidial plate in the male is more distinctly visible than in the female; and the tip of the body appears to taper somewhat more abruptly. Mating is frequent and indiscriminate, usually lasting from 4 to 7 minutes.

From our limited observations we are inclined to believe that the reproductive capacity of this species is considerably less than that of the boll weevil; and its capacity for damage to the cotton crop is, we believe, less than half that of the boll weevil. It is evidently capable of surviving under decidedly arid conditions, as the territory in which these observations were made receives no rainfall and irrigation is practiced only at intervals of several weeks during the fruiting season, and may not occur at all during this period. The species certainly deserves more extended and detailed investigation.

NOTES ON THE COMPUTING OF MEAN TEMPERATURES FOR BIOLOGICAL USE.

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Practically all biological papers give some mention of the effect of various temperatures on the plant or animal under discussion. Considering this striking expression of the importance of the temperature factor it is indeed surprising that biologists have not given more time to the study of temperature means. It is true that we have elaborate devices for the recording and control of temperatures but in correlating the actual outdoor readings with insect and animal activities we are woefully weak. We consider that one of the first steps in correcting this weakness is the study and development of a correct and convenient method for computing mean temperature over a short or long period of time, as the case may demand.

Climatologists are particularly interested in mean temperatures and have made many studies concerning them. However, their interest is usually in an accurate mean temperature for long periods of time, such as a month or a year. For many biological uses, records such as these are obviously unsuited. For instance in working with an aphid that develops from birth to reproductive capacity in seven or eight days in summer, the monthly mean temperature is of little value. This is also the case in any short time biological process. At present the mean temperatures issued by the U. S. Weather Bureau are computed by adding the maximum and minimum temperature for the day and dividing the result by two. Due to the variable changes in temperature during the day this method admittedly is inaccurate and will sometimes vary from the true daily mean, as determined by hourly readings, by as much as 10 degrees F. Also these variations may be cumulative at certain periods, thus increasing their importance. Hartzell (3) has pointed out that if the maximum and minimum readings are taken after 8 p. m. that the discrepancies are much less if a long period of time is considered. Hann (2) recommends that readings be taken at 6 a. m., 2 and 10 p. m. to secure an accurate average, but this also applies to long periods of time. Most biologists use self-recording thermographs and compute a mean temperature by taking hourly or two hour readings from the graphs. This is a laborious and time consuming method to say the least.

Some time ago it was necessary to obtain daily and weekly mean temperatures from data on a drum type soil thermograph that had accumulated over a period of two years. To avoid this lengthy and monotonous task an attempt was made to develop a shorter method. The use of the planimeter in computing mean temperatures has been mentioned by Hartzell (3) and Sanderson (5) but as far as we are aware the technique that was developed in handling this instrument is original. Two methods of computing mean temperature with the aid of the planimeter were devised. First, a method using the total area of the temperature chart as a base of measurement against which the area, either above or below the temperature curve, is computed as a fractional part. Instead of computing this fractional area by arithmetical methods we can easily construct a graph for this purpose. On the abscissa, the units of area in the temperature chart may be plotted. (This must also take into account the time unit, which may be a week, a day or several days. A separate graph should be made for each time unit in which one wishes to compute mean temperature). On the ordinate plot the temperature range of the chart. A curve joining the point of intersection is then drawn. When the fractional area is obtained with the planimeter, locate this on the abscissa and run across the graph to the curve, then drop to the ordinate and the mean temperature is read. It is probable that a method somewhat similar to this was used by Sanderson (5) and Hartzell (3), though we have no example of their technique.

The second method is useful in case we do not wish to construct a graph and have only a few charts to work over. It is more complicated and is given in detail as follows: (Fig. 1, Plate XVI).

1. Obtain the maximum and minimum temperatures for the period of time, any period from one to seven days may be used, during which it is desired to obtain a mean and subtract the latter from the former. This gives the temperature range.

2. Obtain the area bounded by parallel, horizontal lines running through the maximum and minimum readings, and the vertical or time lines inclosing the period to be considered. This is the total area.

3. Likewise obtain the area of that section of the rectangle lying above the temperature curve. This is the fractional area.

4. Divide the fractional area by the whole area. This gives the fractional area in terms of percent.

5. Multiply the temperature range by the percent. The product is degrees of temperature corresponding to the fractional area.

6. Subtract this from the maximum temperature and we have the mean temperature for the period.

The two methods when applied to the same charts give almost identical results. During the course of a year, in which the mean temperature was calculated for each week by the two methods, the maximum difference occurring in any week was .8 degree F. The average difference for the year was less than .3 degree F. The following table gives some idea of the actual differences that occurred between weekly mean temperatures so computed. During this period the 1st method averaged .07 degree F. higher than did the 2nd.

TABLE I.

Comparison of Weekly Mean Temperatures, Computed by the Two Planimeter Methods.

First Method	Second Method	First Method	Second Method	First Method	Second Method
39.8	39.5	59.6	59.2	71.2	71.6
39.0	39.2	66.6	66.3	76.5	76.0
43.3	42.9	63.3	62.7	71.2	70.8
35.4	35.7	46.3	46.1	69.8	69.8
53.9	54.5	48.3	47.9	64.9	65.3
47.8	47.6	52.5	52.2	72.8	72.6
53.2	53.5	58.2	58.3	73.0	72.8
42.6	42.7	62.3	61.6	71.2	71.0
50.0	49.9	81.8	81.7	71.0	71.3
55.4	55.2	70.4	69.9	74.3	74.9
60.1	60.3	72.0	71.5	73.2	73.5
65.0	64.8	66.2	66.2	69.2	69.4

The same systems can, of course, be used in calculating humidity averages.

No sooner had these methods been developed than the question arose as to how closely temperatures so computed would correspond to temperatures calculated by the other methods. I, therefore, took the data from eight weekly sheets, as recorded on a soil thermograph and computed the weekly mean temperature by each of four different methods. These were: daily maximum and minimum readings, twelve daily readings, twenty-four daily (hourly) readings, and the second planimeter method as described above. The weekly maximum and minimum mean was computed by averaging the seven daily means of this type. The mean for the twelve and twenty-four daily readings was found in the same way but the planimeter mean was taken directly from the graph. Figure 2 shows the results of this study. Since the twenty-four daily readings constitute a reliable method of computing the mean, I have plotted this directly on the heavy horizontal line. The other means were then plotted according to the amount of variation from this. The wide variation, from 2 to 5 degrees, between the maximum and minimum mean and the other three means is striking, but even more noticeable is the closeness of the latter three means to each other. The mean as determined by the planimeter varies at most only .3 degree F, while the mean determined by twelve daily readings does not differ more than .1 degree.

Figure 3 shows work with thirty weekly sheets taken from an aerial thermograph. The plan of this graph is the same as Figure 2 except that the planimeter mean is plotted on the horizontal line and the mean as determined by twenty-four daily readings was not computed. There is some indication that at times the planimeter mean is more accurate than the mean of the twelve daily readings. For example, when the maximum and minimum mean shows a wide variation, as in the week of May 25th, this is partially corrected by the mean of the twelve daily readings, which error is still further reduced by the planimeter. The greatest variation in this series amounts to .7 degree F.

We then compared the planimeter method with the others in computing the mean temperature for shorter lengths of time, which of course meant that the areas to be measured by the planimeter would be smaller. Two things led us to fear that the planimeter method would not be accurate on such areas: 1st, the planimeter vernier is not finely graduated and readings from it must at times be approximated; 2nd, in moving the pointer around the area it is not always possible to keep it exactly on the line.

Fifty days were taken at random throughout the year from soil thermograph records and the mean for each was computed by the four methods. Figure 4 is of the same construction as Figures 2 and 3, with the twenty-four daily reading mean plotted on the horizontal line. The variation of the maximum and minimum mean from that of the twenty-four daily readings ranges from 0 to 6.7 degrees with an average error of about 3 degrees. The greatest variation of the planimeter mean is 1.4 degree with an average variation of less than .3 of a degree. This shows the great improvement effected by this method. However, the greatest variation of the mean of the twelve daily readings is .6 of a degree with an average deviation of approximately .1 degree.

Figure 5 gives the same data as Figure 4 but the planimeter mean is plotted on the horizontal line. The very small amount of variation between the means of the twenty-four and the twelve daily readings is clearly shown. This in connection with Figure 4 and together with a close study of the daily curves as they appear on the weekly temperature charts show us that the planimeter mean of daily temperature is not quite as accurate as the means established by twenty-four or twelve daily readings.

The time required to compute a weekly mean temperature, using twenty-four readings for each day, is between 40 and 50 minutes for one's self, a clerk and an adding machine. By using a planimeter one can calculate an accurate weekly mean temperature in about 5 minutes, without the services of the clerk and machine. Because of this great saving in time and labor we believe that the planimeter methods can be used, especially in instances where a mean temperature is desired for periods covering several days or a week.

To summarize briefly, the mean temperature computed by the planimeter for periods as short as a day is not quite as accurate as the means of the twenty-four or twelve daily readings. It is, however, a great improvement over the usual maximum and minimum mean. The mean of twelve daily readings is, for most purposes, practically as accurate as the mean of the 24 daily (hourly) readings.

The planimeter mean as determined for periods of time such as a week is accurate and convenient and because of this can be used to advantage.

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EXPLANATION OF PLATE XVI.

Fig. 1. An example of the planimeter method.

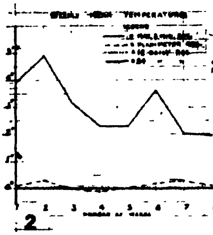
Fig. 2. Weekly mean temperatures as computed by four different methods. Twenty-four daily reading mean plotted on the base line.

Fig. 3 Weekly mean temperatures. Planimeter mean plotted on the base line.

Fig. 4. Daily mean temperatures. Twenty-four daily reading means on the base line.

Fig. 5. Daily mean temperature. Planimeter mean on the base line. (Same data as Fig. 4)

Fig. 6. Difference between mean temperatures as determined by the maximum and minimum and the planimeter method. Actual weekly mean temperatures for a portion of 1925 at Oak Harbor, O.



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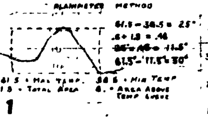

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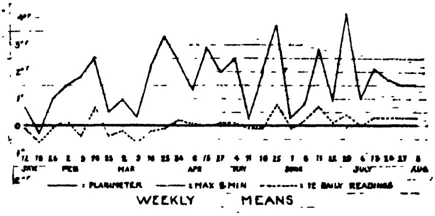

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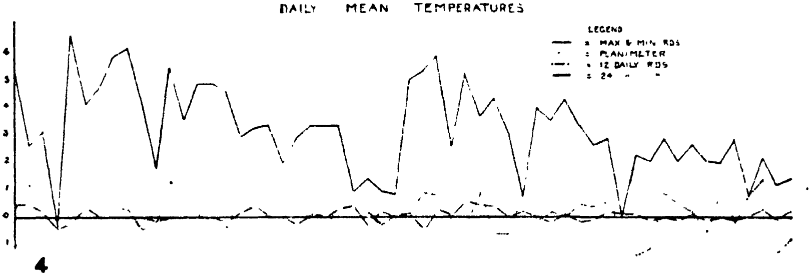

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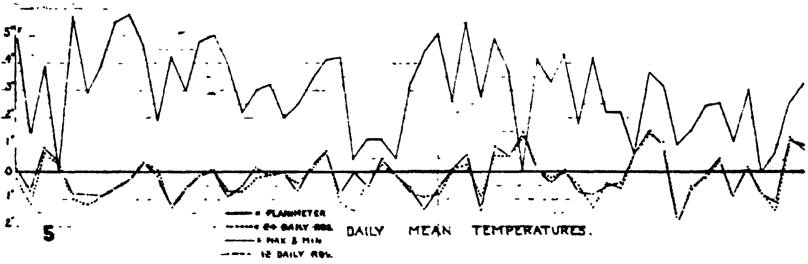

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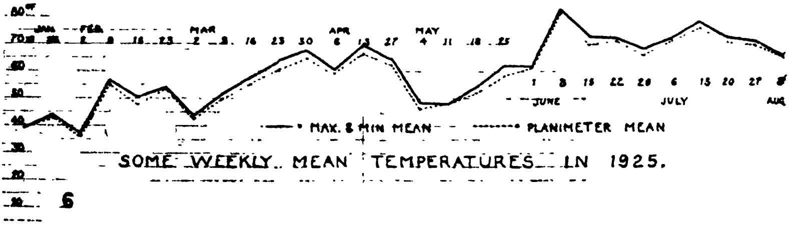

6

C. R. Cutright

A NEW SPECIES OF HYDROMETRA FROM NORTH AMERICA.

H. B. HUNGERFORD,
Department of Entomology, University of Kansas, Lawrence.

In a collection of some aquatic Hemiptera sent to me by Mr. Clarence O. Bare I find a species of Hydrometra that is not described in Mr. J. R. de la Torre-Bueno's splendid paper entitled "The Family Hydrometridæ in the Western Hemisphere" which appeared in the *Entomologica Americana* Vol. VII (New Series) No. 2, issued December 27, 1926.

Hydrometra barei sp. new.

Size: Length of male, 7.5 to 8 mm. Length of female, 9.3 mm. The head is not provided with a ventral groove. The anteocular portion of the head is to the postocular portion of the head as forty-three is to twenty-three, the formula being therefore AO : PO :: 43 : 23. The tip of the rostrum surpasses the eyes by three-fifths of the postocular distance. The anterior femur does not attain the base of the antenna. The relation of the segments of the antennæ beginning with the basal one is represented by the following formula: 10 : 20 : 55 : 28 in the male. The female segments are slightly shorter proportionately. The male processes on the ventral side of the sixth segment are linear, oblique and located near the anterior margin. The distance between these processes is more than twice the length of either process.

The caudal spine of the male is long, straight and directed backward. The last segment of the male viewed from above is very slightly expanded in its caudal portion and longer (including the spine) than the preceding segment. The caudal spine of the female is also long, sharply acuminate and four-fifths as long as the preceding segment surpassing the tip of the body by nearly half its length. Two pits are present on the pro and meso-acetabula.

Described from two pairs taken at Plant City, Florida by Mr. C. O. Bare. Holotype and allotype in the University of Kansas Entomological Collection.

THE VARIABILITY OF APHIS GOSSYPII.

C. H. Batchelder,
University of Maine.

SUBJECT MATTER.

Purpose of the investigation.
Source of the material
Technique employed.
The variability of external characters.
The correlation of external characters for length.
Varibility and the foodplant.

The Purpose of This Investigation.

Because of confusion in economic literature and in collections, concerning the identity of *Aphis gossypii*, it is desirable to know the range of variation in this species, especially with reference to such external structures as may be considered of value as "key characters."

Source of The Material.

The original stock collections were made by Dr. Edith M. Patch from garden cucumber, *Cucumis sativus*, on August 21, 1923. The stock was kept on squash, *Cucurbita maxima*, under laboratory and insectary conditions through several generations and from this host-plant transfers were made as follows:

Sublot 2; squash, from which material was mounted on September 30, October 4, October 25, November 20, and November 26.

Sublot 4; to Begonia on August 28, from which material was mounted on October 4, October 25, and November 20.

Sublot 5; to Shepherd's Purse on September 20, from which material was mounted on October 4.

Sublot 6; to squash in air temperature insectary on August 21, from which material was mounted on October 23.

Sublot 7; to Oenothera biennis on September 20, from which material was mounted on November 20, December 1, and December 24.

It will be noted that this method of collecting the material made available for examination only plant-lice that had been bred under controlled conditions. This precluded the introduction of species other than *A. gossypii*. Conditions were otherwise controlled consistently enough to expect comparative uniformity in the specimens.

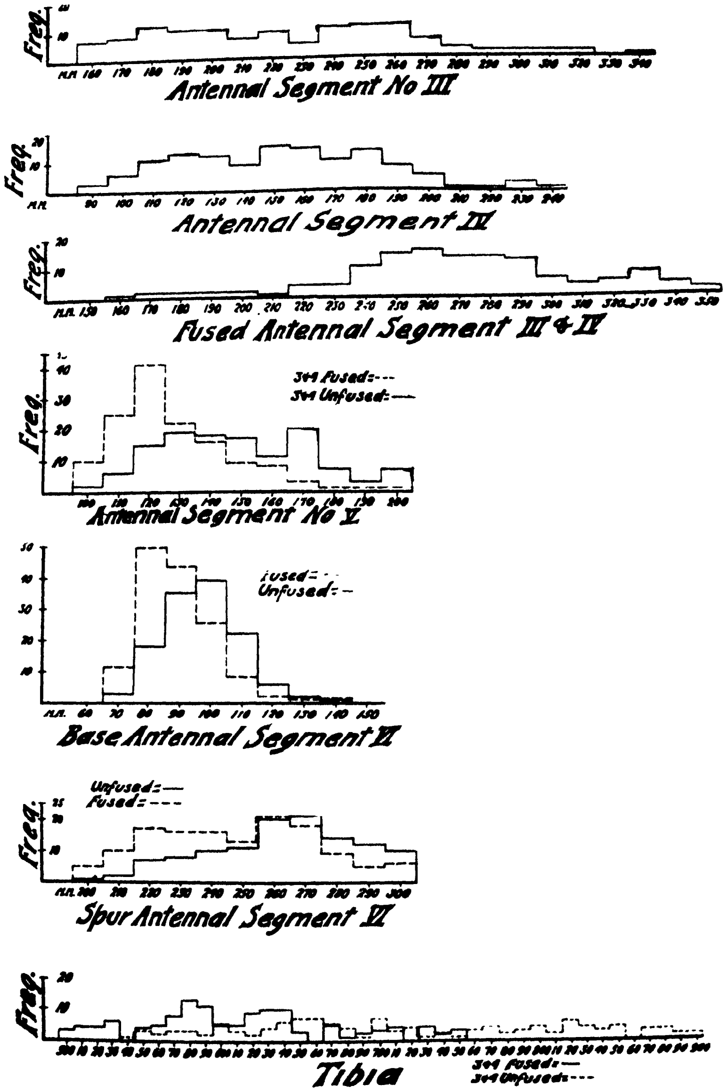

Fig. 1. Histograms illustrating the variability in length of antennal segments and the metathoracic tibia in the wingless form of *Aphis gossypii*. Antennæ in which segments 3 and 4 are fused are compared in length with those in which these segments are not fused.

THE TECHNIQUE EMPLOYED.

Balsam mounts had been very carefully made on the collection dates mentioned above. In addition, preparations of *A. gossypii* were available from *Cucumis melo*, *Cucurbita pepo*,

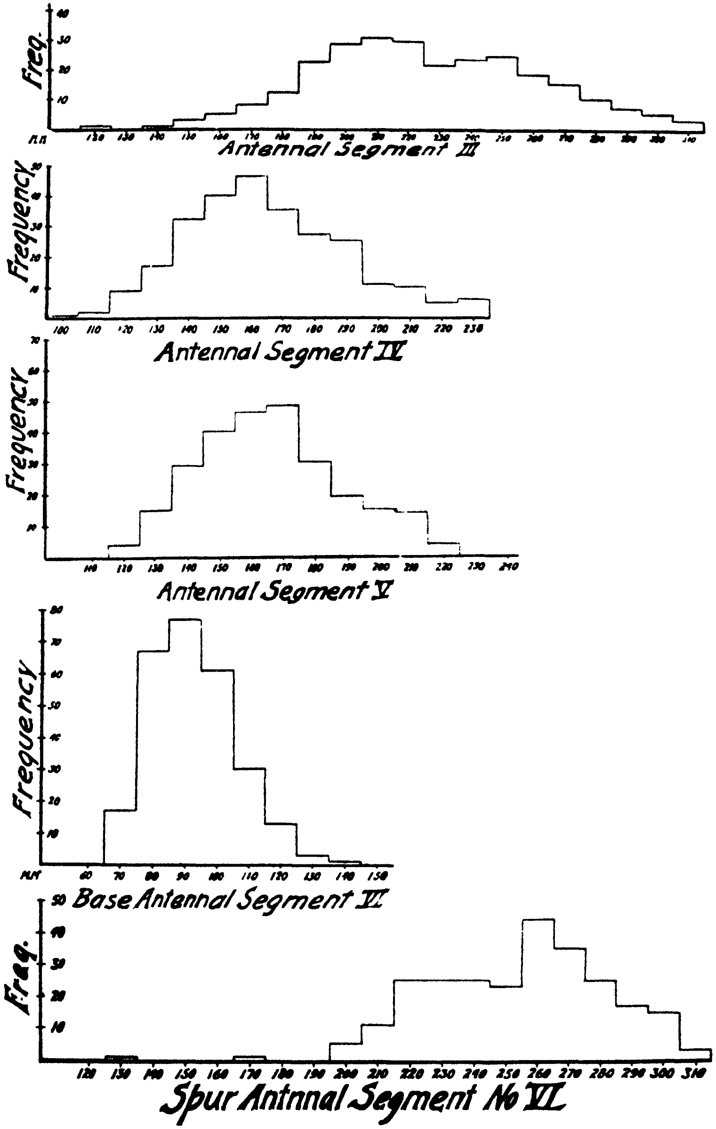

Fig. 2. Histograms illustrating the variability in length of antennal segments in the winged form of Aphis gossypii.

Veronica officinales, *Rumex acetosella*, *Malva rotundifolia*, and *Fragaria virginica*. This mounted, adult material, which included 266 winged viviparæ and 265 wingless viviparæ, was now examined and measurements were taken as follows; (1), the individual antennal segments, (2), the cornicles, (3), the metathoracic tibiæ, and (4), the cubitus vein of the wing. For this purpose a microscope was fitted with an 8 mm. objective and a camera lucida. And these being clamped in position, the divisions of one millimeter to hundredths was projected on bristolboard and a scale drawn for measuring characters. An antennal segment, for example, being projected at the same magnification as the millimeter scale, could be measured with a very satisfactory degree of accuracy. As all characters examined, with the exception of some of the cubitus veins of the wings and a few tibiæ, were less than one millimeter in length, this scale was quite sufficient for the purpose. The method was employed in making 3,830 measurements.

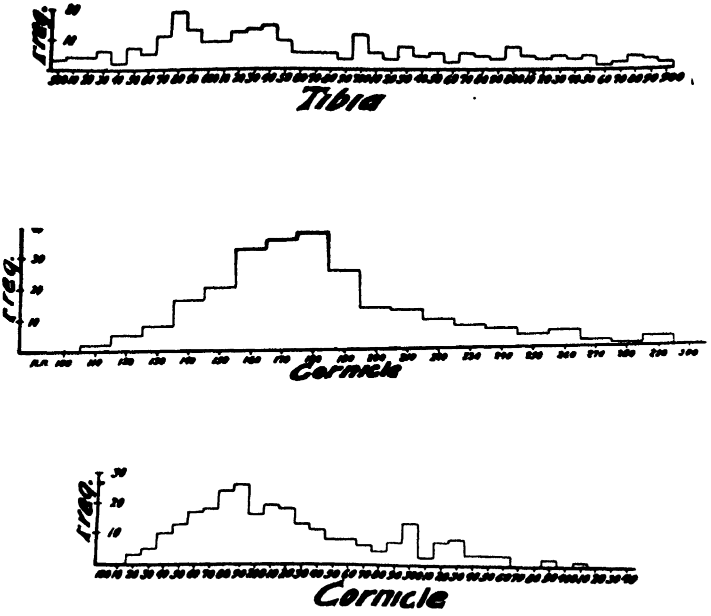

Fig. 3. Histograms illustrating variability in the lengths of the tibia and the cornicle in the alate viviparous form of Aphis gossypii. Histogram illustrating variability in the length of the cornicle in the apterous viviparous form of Aphis gossypii in which the antennal segments are not fused.

THE VARIABILITY OF EXTERNAL CHARACTERS IN APHIS GOSSYPII.

The most obvious variation in this species occurs in the number of antennal segments (Fig. 4) of the wingless form. Of 264 aphids examined, 138 of them, or 52 percent, possessd antennæ made up of five segments, a condition apparently due to fusion of segments III and IV. The remaining 126 aphids possessed antennæ in which segments III and IV were distinct. Tabulating all of the measurements taken according to whether the antennæ were five or six jointed it was found that the fusion of segments of III and IV is correlated with general reduction in length of the body, the cornicles, and the metathoracic tibiæ. But exceptions to this are not difficult to find, and it would be incorrect to express the correlation as being absolute. *In stating the length of external characters for this insect, however, it is evident that a distinction should be made between these two types of the apterous form.* A comparison of the data collected for these two types will serve to illustrate this point. If histograms are constructed from the data obtained by measuring the length of antennal segment V, the base and the spur of antennal segment VI, the tibia, and the cornicle; then, it will be found that the frequency of the distribution differs in these two types of the apterous form. The base of antennal segment VI, for instance, has a mean length

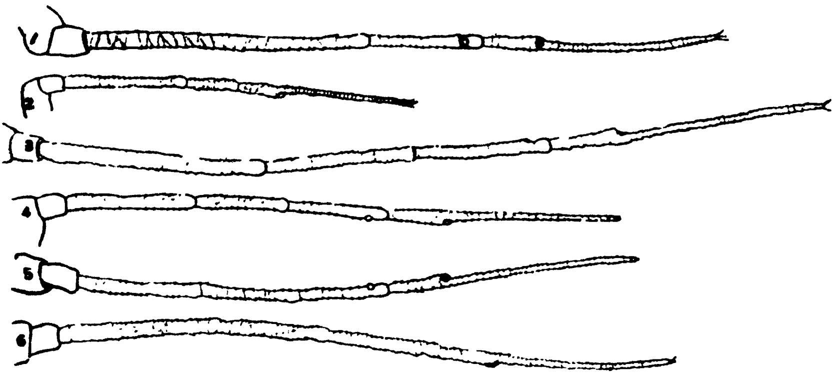

Fig. 4. Illustrating variability in the antennal segmentation of the wingless form of *Aphis gossypii;* 1 and 2, maximum and minimum antennæ of 5 segments. 3 and 4, maximum and minimum antennæ of 6 segments. 5, illustrating the appearance of the antennæ in many specimens of Aphis gossypii in which the segmentation is very indistinct. 6, the antenna of an individual collected from the same colony and mounted at the same time with No. 2.

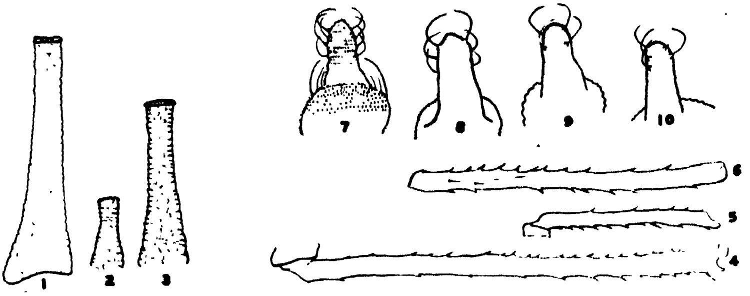

Fig. 5. Illustrating variability of *Aphis gossypii;* 1 and 2, extremes in the length of the cornicles in two apterous forms. 3, the cornicle of an apterous individual collected from the same colony and mounted at the same time with No. 2. 4 and 5, extremes in the length of the tibia of apterous forms. 6, the tibia of the same individual from which cornicle No. 2 was taken. 7, 8, 9, and 10, are variations in the size, shape, number, and position of caudal hairs in the apterous form, in which it should be noted that the highly distinctive, incurved, terminal extremity of the most posterior hairs is characteristic throughout the series.

of .080 mm. in the 138 aphids having III and IV of the antenna fused, and the mean length of the base in the 126 individuals with III and IV distinct is .100 mm. while the average length of the base in the 264 aphids, if a general average is taken, is .094 mm. To illustrate graphically the influence of this fusion of segments III and IV, histograms were constructed to show the frequency in distribution of the data taken for these two types (reference should be made to them in Figures 1, 2, and 3).

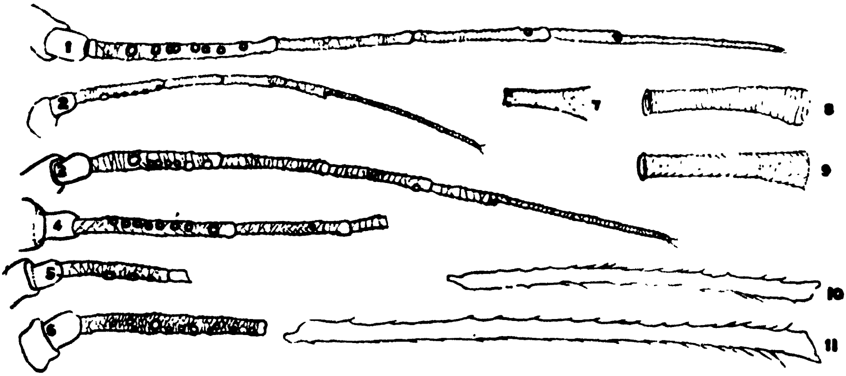

Fig. 6. Illustrating variability in the winged form of *A. gossypii.* 1 and 2, extremes in the length of the antenna. 3, the average appearance, number, position, and distribution of the sensoria. 4, the sensorium appears occasionally on segment IV. 5 and 6, extremes in the number of sensoria. 7 and 8, extremes in the length of the cornicle. 9, the cornicle of an individual taken from the same colony from which No. 7 was taken. 10 and 11, extremes in the length of the metathoracic tibia.

Furthermore, it should be noted that the fusion of III and IV is not equal to the combined length of the two segments. The average length of III was found to be .224 mm., of IV it was .160 mm. and these combined (.385 mm.) are in excess of the average length of III and IV in the fused condition, (.286 mm.). Thus it will be seen that in the latter type of the apterous form, the total length of the antenna is shortened since the reduction is not made up by segments V and VI.

The variability of the apterous form of *A. gossypii* was given additional attention in the matter of the length of the antennal segments, the tibiæ and the cornicles, and the data obtained are expressed in frequency histograms and are summarized in the following tables:

TABLE I.

Extremes in the variation of length of external characters found in the apterous viviparous form of 264 individuals of the species, *Aphis gossypii*. The data given here are selected on the basis of the possession of either 5 or 6 antennal segments, referred to as the fused or the unfused type.

Unit	FUSED TYPE				UNFUSED TYPE			
	Maximum	Aphid No.	Minimum	Aphid No.	Maximum	Aphid No.	Minimum	Aphid No.
Ant. Seg. III	.444	476-6	.155	571-0-8	.428	571-Q-12	.138	571-Q-7
Ant. Seg. IV..	.			. .	.244	571-K-1	031	486- 2
Ant. Seg. V.	.224	571-K-1	095	571-Q-4	.218	571-K-1	.104	571-Q-6
Ant. Seg. Base VI	.137	476- 6	067	571-C-4	.202	571-Q-12	072	498- 5
Ant. Seg. Spur VI..	.320	571-K-1	132	573- 8	.340	481- 3	204	571-Q-6
Tibia.	1.008	571-K-1	453	571-Q-4	1.027	571-K-1	414	585-A-6
Cornicle. .	.346	475- 1	.115	571-Q-4	.413	571-K-1	.133	587- 1

TABLE II

The average length of the external characters found in a study of 264 individuals of the apterous viviparous form of Aphis gossypii. The means are selected according to antennal type.

Unit	Average	Fused Type Mean	Unfused Type Mean
Ant. Seg. III	.224	......	240
Ant. Seg. IV..	.160	.....	150
Ant. Seg. V	140	120	.170
Ant. Seg. Base VI	.094	080	.100
Ant. Seg. Spur VI	254	260	270
Tibia	.675	580	700
Cornicle	238	180	190
Ant. Seg. III, IV	385	..	390
III, IV Fused.	286	260	.....

Reference should be made to the material in figures 4 and 5 illustrating extremes in length of these characters.

The alate, or winged form of *Aphis gossypii* was examined in the same manner. Measurements were taken of Antennal segments, III, IV, V, and the base and spur of VI, the cornicle, the tibia, and the cubitus vein of the wing. In addition, the number of sensoria on right and left segment III was noted. Text figures of extreme and normal conditions are offered in figures 5 and 6 and the data obtained from measuring the external characters of 266 alate individuals are expressed in frequency histograms (figures 2 and 3) and are summarized in the following tables:

TABLE III

Extremes in the variation of length of external characters found in a study of 265 individuals of the alate viviparous form of Aphis gossypii. This is accompanied by a list of the various aphids from which these measurements were taken.

Unit	Maximum	Aphid No.	Minimum	Aphid No.
Ant. Seg. III	.325	588-2-1	.119	498- 6
Ant. Seg. IV	.235	571-L-2	.102	571-Q-3
Ant. Seg. V	.227	571-K-2	.115	571-Q-3
Ant. Seg. Base VI	.127	571-K-2	.077	571-Q-3
Ant. Seg. Spur VI	.375	571-K-2	.237	571-5-3
No. Sensoria, R	12.	573- 4	3.	571-Q-2
No. Sensoria, L	12.	639- 7	4.	571-Q-3
Tibia	1.079	583- 1	.462	571-Q-9
Cornicle	.292	648-C-1	.112	571-Q-14
Cu Wing	1.895	593- 1	.647	571-L-1

TABLE IV

The average and the mean lengths of external characters determined in a study of 265 individuals of the alate viviparous form of Aphis gossypii. Reference should also be made to the material in figure 6 illustrating extremes in the length of these characters.

Unit	Average	Mean
Ant. Seg. III	.241	.210
Ant. Seg. IV	.174	.160
Ant. Seg. V	.173	.170
Ant. Seg. Base VI	.107	.090
Ant. Seg. Spur VI	.307	.260
No. Sensoria, R	7.2	....
No. Sensoria, L	7.2	....
Tibia	.818	.700
Cornicle	.192	.180
Cu Wing	1.008	....

CORRELATION OF EXTERNAL CHARACTERS FOR LENGTH.

Having established the extent of the variation of the external characters of *Aphis gossypii*, let us consider the value of these parts as key characters. An examination of the frequency histograms expressing the variability of the apterous viviparous form will reveal in several instances fairly normal curves, and it would appear that dependable correlation exists between two or more characters which might be useful in establishing the identity of the insect. But this is misleading. Reference to Table I indicates that little relation exists between the growth of any two external organs or parts of organs. It will be noted that the maximum and minimum dimensions constituting this table are not taken from a single large, or a single small aphid, but that it is a composite, no duplicate of which was found in nature. The data represent rather, the limits of growth of any one segment or organ. Absence of uniform growth in this aphid was confirmed in a study of the coefficient of correlation of external characters.

TABLE V

Correlation surface for the length of the base compared with the length of the spur of antennal segment VI. The data are taken from 116 individuals of the apterous viviparous form in which antennal segments III and IV were not fused.

	LENGTH OF ANTENNAL SEGMENT VI—SPUR									
LENGTH OF ANTENNAL SEGMENT VI—BASE	210–219	220–229	230–239	240–249	250–259	260–269	270–279	280–289	290–299	Total
60–69				1	1					2
70–79	1		3	0	2	2			1	9
80–89		4	3	3	4	10	5	3	4	36
90–99		2	3	3	3	4	9	6	7	37
100–109			1		2	7	4	2	5	21
110–119			1			2		3	5	11
120–129										
Total	1	6	11	7	12	25	18	14	22	116

Assuming from the frequency of distribution, as well as from the terminal position and the function of antennal segment VI, that the growth ratios of its two component parts, the base and the spur, might be comparatively uniform, a correlation surface was determined for the length of the base and the length of the spur of segment VI. The data for this comparison, taken from the apterous type in which III and IV are not fused, are shown in Table 5.

TABLE VI.

Correlation surface for the length of the spur of antennal segment VI compared with the length of the cornicle. The data is taken from 123 individuals of the apterous viviparous form in which antennal segments III and VI are not fused.

LENGTH OF ANTENNAL SEGMENT VI SPUR (3 AND 4 NOT FUSED).

LENGTH OF CORNICLE	200–209	210–219	220–229	230–239	240–249	250–259	260–269	270–279	280–289	290–299	300–309	310–319	320–329	330–339	340–349	350–359	Total
120–129																	
130–139				1													1
140–149	1	1											1				3
150–159	1	1	1				1	2									6
160–169		1		2		1						1					5
170–179				1		1		1			1						4
180–189			1	1		1	6	2				1					12
190–199			2	1		1	2	1	1								8
200–209			2	1	1	1	1	2	2	1							11
210–219																	0
220–229			1	1		3	3	4									12
230–239			1			1		1	1			1					5
240–249				1	1						1						3
250–259							2	1	1								4
260–269				1			2		1	1	2						7
270–279								1									1
280–289							1		2	1		1					5
290–299				1			2	1	1		1						6
300–309				1	1				1	1							4
310–319							1	1		1			1				4
320–329			1		1		2				1						5
330–339							1	1	1	1	2						6
340–349					1		3	1	1	1			2	1	1		
Total	2	3	9	12	5	9	24	19	12	8	8	3	4	1	1		

From Table 5 was derived a more definite statement of the extent of the variability of the growth ratios of the base and the spur. The mean length of the base is found to be .094 mm. and its standard deviation from the mean is .0115. The mean length of the spur is found to be .267 mm. and its standard deviation from the mean is .021. Computing the coefficient of correlation for the base and the spur we have, Rxy = .0217 ±.062 a figure so small as to indicate that no correlation exists at all. Thus, we arrive at the conclusion that the factor governing the growth of the base of segment VI has no relation to that factor which limits the rate or extent of growth of the spur of the same segment. And concomitant with this is the fact that these two are valueless as "key characters."

TABLE VII.

Correlation surface for the length of the metathoracic tibia compared with the combined lengths of antennal segments III and IV. The data are taken from 119 individuals of the apterous viviparous form in which antennal segments III and IV are not fused.

COMBINED LENGTHS OF ANT. SEGS. III, IV	LENGTH OF TIBIA. 500–524	525–549	550–599	575–599	600–624	625–649	650–674	675–699	700–724	725–749	750–774	775–799	800–824	825–849	850–874	875–899	900–924	925–949	Total
200–224	1				1			1											3
225–249				1															1
250–274		3	4	3	1				1										12
275–299	2		2	1	5	2	1									1			14
300–324				1	2	4	3												10
325–349					1	4	3	2	3										13
350–374						2	1	5	4	1	1								13
375–399									1	1	1		1	1					5
400–424									1	3	3	3	3	2	2				17
425–449											1	3	2	3	3	3	1		16
450–474											3	1	1	1					6
475–499															1		1	1	3
500–524													1				1		2
525–549																1		2	3
	3	3	6	6	10	12	8	8	10	5	9	7	8	7	6	5	3	3	

The length of the cornicle as compared with the length of the spur of antennal segment VI offers another possibility as a key character in aphids and the relationship was determined. The data for the comparison, taken also from the apterous type in which segments III and IV are not fused, are shown in Table 6.

From these data, computation discloses little of value in these characters for determining the species under consideration. The coefficient of correlation, Rxy = .4496 ± .0613, is again so small as to indicate that practically no dependable correlation exists between the lengths of these two characters.

Some promise of key value was offered by comparing the lengths of the tibiæ and the combined lengths of segments III and IV in the unfused type of the apterous form. The data for comparison are shown in Table 7.

The figures in this instance offer somewhat more promise in the correlation table, and computation reveals a coefficient of correlation of .08691±.0149 which indicates a very close relation between the factors governing the growth ratios of these organs. It would appear, therefore, that this is a fairly dependable character and as such it is an exception in an aphid characterized by remarkable variability.

TABLE VIII.

Correlation surface for the length of the base compared with the length of the spur of antennal segment VI. The data are taken from 263 individuals of the alate viviparous form of Aphis gossypii.

LENGTH OF ANTENNAL SEGMENT VI—BASE.

LENGTH OF ANTENNAL SEGMENT VI—SPUR	.070-.079	.080-.089	.090-.099	.100-.109	.110-.119	.120-.129	Total
.230-.239				1			1
.240-.249							0
.250-.259		2		3			5
.260-.269	1	4	4	6	1		16
.270-.279			10	9	3	1	23
.280-.289		4	9	14	5	1	33
.290-.299		1	11	19	7	1	39
.300-.309			12	26	14	6	58
.310-.319		1	3	18	12	3	37
.320-.329			2	8	10	6	26
.330-.339			1		6	2	9
.340-.349			1	2	1	3	7
.350-.359				1	1	1	3
.360- 369					1	2	3
.370-.379					3		3
Total	1	12	53	107	64	26	263

This tendency in individual segments or appendages to vary independently is illustrated in Table I but is more noticeable in an examination of summarized data. The condition seems to be one in which an aphid may be endowed with a large tibia even though the body, cornicles, and most of the antennal segments, are small, or it may be the possessor of a large pair of cornicles while the tibiæ, body, and antennal segments are comparatively small, and so on. No explanation of this seeming lack of proportion is immediately apparent. It appears to have a nutritional basis and it might be ventured that, since the embryo tends to develop to uniform proportions, the rapidity of growth of embryos may not be commensurate with the food intake, especially during nymphal stages of the viviparous mother. If the physiological balance in this species is adjusted with respect to reproduction rather than to the development of adult characters, then such a condition of variability as exists in Aphis gossypii might be expected. However, this is entirely hypothetical.

TABLE IX.

Correlation surface for the length of antennal segment IV compared with the length of antennal segment V. The data are taken from 266 individuals of the alate viviparous form of Aphis gossypii.

LENGTH OF ANTENNAL SEGMENT IV.

LENGTH OF ANTENNAL SEGMENT V	100–109	110–119	120–129	130–139	140–149	150–159	160–169	170–179	180–189	190–199	200–209	210–219	220–229	230–239	Total
110–119		1													1
120–129	1	1	4												6
130–139	1	1	6	9	2	1	2	1							23
140–149			6	12	10	8									36
150–159				5	11	12	8	5	1						42
160–169					7	12	15	15	5		1				55
170–179					2	7	13	4	7	1	2	1			37
180–189						4	2	6	10	1	3	2			28
190–199								1	3	4	1	3	1		13
200–209								1	2	2	2	3	2		12
210–219									2	1	1	2	2	1	9
220–229											1	1	2		4
Total	2	3	16	26	32	44	40	33	30	9	11	12	7	1	266

The coefficient of correlation here, Rxy = .4689 ± .0328, is too low for utilization of these characters.

More promise, however, is indicated for antennal segments IV and V in the alate viviparous form and the data for the comparison of these two segments are shown in Table 9.

Here the coefficient of correlation is unusually high, being expressed Rxy = .9275 ± .0057 and there is every indication that the relationship of these two characters constitute a highly valuable means of distinguishing the species when used in conjunction with other characters.

VARIABILITY AND THE FOODPLANT.

In order to determine the extent of the tendency of the summer forms of Aphis gossypii to vary on its different foodplants, data were assembled from colonies of the insect that were kept on several of its common hosts. Collections were mounted on various dates as previously described and since these collections included not only representatives of the aphids of average size, but also the largest and the smallest individuals at that time, it was possible to obtain a comparison of the influence of several foodplants on the variability of this species. Table 10 summarizes the data.

TABLE X.

Extremes of variability of the apterous viviparous form on various foodplants. The data are taken from individuals in which the antennal segments III and IV are not fused.

	Cucumber		Squash		Begonia		Oenothera	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Ant. Seg. III	315	234	428	138	238	157	261	125
Ant. Seg. IV	226	031	194	100	163	115	160	095
Ant. Seg. V	196	130	107	114	167	118	166	107
Ant. Seg. Base VI	090	081	202	081	106	084	107	072
Ant. Seg. Spur VI	340	226	234	206	319	255	247	240
Tibia	955	585	867	588	732	566	735	496
Cornicle	359	194	302	152	231	160	203	141
Ant. Total	1,167	702	1,165	639	993	729	941	639

It should be noted in table 10 that the greatest variation between the largest and the smallest aphids taken on these plants occurs in those taken from squash. It is of interest to note that both of these individuals were taken on the same day, November 11, 1923. The least amount of variation occurred on Oenothera, where, again the two extremes were taken at the same time. It would be illogical, however, to attach any especial significance to the degree of variability observed here. The aphids grown on Oenothera are somewhat smaller than those produced on squash but they are unusually variable just the same. So far as available data show there is nothing to indicate that Aphis gossypii is not an unusually variable insect no matter what foodplant it happens to colonize.

SUMMARY.

1. Mounted specimens of Aphis gossypii (adult) were examined and measurements were taken of the individual antennal segments, the cornicle, metathoracic tibia, and the cubitus vein of the wing. The material so examined and measured included 266 winged viviparæ and 265 wingless viviparæ.

2. Of the wingless viviparæ 52% were found to possess antennæ made up of five segments, a condition apparently due to fusion of antennal segments III and IV. The remaining 48% of the wingless viviparæ were found to bear antennæ made up of six distinct segments.

3. It is apparent that the same factor which causes fusion of antennal segments III and IV usually causes reduction in the length of the body, the cornicle, and the metathoracic tibia.

4. The maximum and minimum dimensions of the external structures in this insect were found to be separated by unusually wide limits. The extent of the variation is set forth in frequency histograms, comparative tables, and illustrative figures.

5. A study of the correlation of the dimensions of the external structures indicates that there is an absence of uniform growth rate throughout the insect and that little correlation exists in the rate of growth of any two parts. The condition seems to be one in which an aphid may be endowed with a large tibia even though the body, cornicles, and most of the antennal segments, are small. Or, it may be the possessor of a large pair of cornicles while the tibiæ, body, and antennal segments are comparatively small, and so on. No explanation of this seeming lack of proportion is immediately apparent.

6. An exception to the foregoing was found in the apterous viviparous form in which antennal segments III and IV are not fused. Here, correlation was found to be fairly constant between the combined length of antennal segments III plus IV and the length of the metathoracic tibia, the tibia being consistently more than twice the length of III plus IV.

7. In the alate viviparous form correlation was found to exist between the length of antennal segments IV and V.

8. While somewhat greater diversity in size occurs among individuals inhabiting squash than among those colonizing

oenothera, the tendency to vary is exhibited in a pronounced degree and this was found to be true of the species on the several host plants from which the material was taken. There is nothing to indicate that *Aphis gossypii* is not an unusually variable insect no matter what food-plant it happens to colonize.

9. A technical description of Aphis gossypii based on the data of this study may be useful in establishing the exact identity of this insect.

TABLE XI.

The external characters of *Aphis gossypii;* the mean lengths as indicated in a study of 266 winged viviparæ and 265 wingless viviparæ. The means for the number of sensoria on the right and on the left antennæ are also given. This table may be used in establishing the identity of *Aphis gossypii.*

	APTEROUS VIVIPARAE.		Alate viviparæ
	Fused Form*	Unfused Form	
III	286	.240	.210
IV	....	150	.160
V	.120	.170	.170
VI—Base	.080	100	.090
VI—Spur	.260	.270	.260
Sensoria R	....	....	7.
Sensoria L	....	....	7.
Tibia	.580	.700	.700
Cornicle	.180	.190	.180
Cubitus vein	....	....	1.008

*Apparently III and IV fused.

BOOK REVIEW.

THE INSECTS OF AUSTRALIA AND NEW ZEALAND, by R. J. Tillyard; 560 pages, 1,256 figures, including eight colored plates with 261 figures. Published by Angus and Robertson, Ltd., Sydney, Australia.

This is the most remarkable general text of entomology that has appeared recently in that it gives the entomological world for the first time a general view of the many curious and interesting insects of the Australian region. The reader has paraded before his vision a long series of wierd living fossils that have been preserved in Australia since its isolation in the early Tertiary. The volume includes keys to all families with a statement of the number of species known in each in Australia and New Zealand, usually also giving one or more excellent figures of species in the family. With few exceptions, all figures are original, many of the text figures having been made by the author, while Mrs. Tillyard painted the beautiful colored plates. The text figures are especially valuable in emphasizing exact morphological character. The volume represents much more labor than is usually put into such a work as the author had no preceding text to follow and nearly all keys had to be written directly from Australian material because of the many primitive forms that as connecting links would not fit into keys already developed in Europe and America. The book is beautifully printed, a variety of type having been used cleverly and artistically.

C. H. KENNEDY.

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ETHOLOGICAL OBSERVATIONS ON SOME PYRRHOCORIDÆ OF CUBA.*

(Hemiptera-Heteroptera).

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1. INTRODUCTION.

The cotton-stainers or bugs of the Pyrrhocorid genus *Dysdercus* are already the subject of an extensive literature. The curtailment of their activities is a frequent task of the applied entomologist in the tropics. The studies here reported on Cuban cotton-stainers and their relatives were made from a point of view which has rarely been previously engaged with these insects. At Soledad, Cuba, where the writer was privileged under an E. F. Atkins Harvard Fellowship to spend most of February, March and April, 1925, no Malvaceous crops of importance are grown, and for this simple reason, cotton-stainers present no very pressing economic problem. So far as the limited time allowed, and in the intervals of other work, their life-histories were studied for their intrinsic interest to the Hemipterist, and their general ethology investigated with regard to its possible bearing on the theory of warning colouration. On both counts the results are very incomplete, and it should be especially emphasised that they were all gained under dry season conditions. Wet season experience would perhaps modify some of the conclusions drawn, and would almost certainly show the cotton-stainers associated with other plants.

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*No. 3, Studies from the Biological Laboratory of Cuba (Atkins Foundation of the Harvard Institute for Tropical Biology and Medicine).

I owe very hearty thanks to the many people who helped me in Cuba. I must especially mention the late Mr. E. F. Atkins, Mrs. Atkins and all the members of the Soledad administration for their assistance and kind hospitality. To Mr. Gaspari my companion and I were indebted for all facilities at the Mina Carlota, Trinidad Mountains, and for the loan of a house in that beautiful and profitable collecting-locality. For other assistance and especially for aid in the determination of the various organisms mentioned in this paper, I thank the following,—Professor Wm. M. Wheeler (ants), Dr. T. Barbour (vertebrates), Mr. Nathan Banks (Arachnids), Mr. R. M. Grey (plants), Mr. George Salt, my companion in Cuba, Mr. H. G. Barber (Pyrrhocoridæ) Professor B. L. Robinson and Mr. C. A. Weatherby of the Gray Herbarium (plants).

2. THE PRE-ADULT STAGES OF *Euryophthalmus sellatus* (GUER).

(a) *Eggs.*—A pair of adults taken *in copula* in the Harvard Botanical Garden on the 7th of February, resumed copulation after installation in the laboratory. The male having died on the 16th, the female deposited on the morning of the 21st or during the previous night, a mass of eggs, and died in her turn on the 27th. The eggs were grouped on the floor of the tube in a close spheroidal mass about 5 millimeters in diameter, and resembling a spider's egg-ball, but much less regular in shape—the pointed, almost fusiform eggs projecting in all directions. The colour at that time was a very pale yellowish, almost white, and the surface shining. By the 2nd of March the eggs showed a faint salmon tint. Seven days later the choria seemed to be shrivelling, and it was feared that hatching would not occur, but on the 10th a young nymph emerged from every one.

Alcohol specimens, measured a year later, were 1.3. mm. long by 0.68 wide. The chorion was smooth and shining, apparently impunctate; the chorial processes nine in number, squat, somewhat cup-shaped tubercles with an opening at the top, and arranged round the upper pole of the egg some distance from the apex. It will thus be seen that the egg of *E. sellatus* is very similar to that of *E.* (*Largus*) *succinctus* (L.), of North America, as described by Heidemann in 1911 (*Proc. Ent. Soc. Wash.*, vol. 13, p. 134) but is slightly smaller.

Hatching was effected by means of a longitudinal split beginning at the upper pole within the circle of processes and proceeding to about the middle of the egg.

No eggs were observed in the field, but since some twigs and leaves were present in the tube with the above female, it is probable that eggs in the field, as in the laboratory, are deposited on the ground, among surface debris, as in *Dysdercus*. Such also, according to Sanderson, is the habit of *E.* (L.) *succinctus*.

(b) *The nymphs.*—The nymphal instars are remarkable for the striking colour schemes which they present in the different stadia, and for the violent contrast between these and the colouration of the imago. A similar development is recorded by Morrill in *E. succinctus*.

The newly hatched nymphs lived in the laboratory only six days, at first spending the whole time closely clustered together, but later roaming actively during the day and massing together during the night in a piece of rolled sugar-cane leaf. Perhaps death was due to lack of suitable food; but on the other hand many Pentatomids are known to take no food during the first nymphal stadium.

The *first instar* is 1.4. mm. in length of body, short and squat in form, with the head, antennæ, thorax and first abdominal segment dark fuscous, almost black, and the rest of the abdomen and the eyes red. The scent-gland orifices are ringed with fuscous and connected by a deeper red flush, while the connexivum posteriorly is speckled with black. The legs are smoky.

I have no evidence as to the number of instars which show this black and red colour pattern. The larger nymphs, which were the only ones discovered in the field during my sojourn, are of a brilliant metallic steel-blue. Rearing records enable only the penultimate and the last instars to be determined satisfactorily, but the antepenultimate also is probably steel-blue.

Penultimate instar.—Length, 4.7 mm. The colour is almost wholly metallic dark greenish blue with violet reflections; eyes bright red, legs and antennæ reddish black, paler at the joints, tegminal pads hiding the metathoracic wing-pads and just reaching the base of the abdomen.

Ultimate instar.—Length, 6.5 to 7.3 mm. The colour is similar to that of the previous stage, but the femora are all bright orange red and there is a spot of the same colour on each side of the base of the abdomen, dorsally.

At ecdysis the split is extremely wide and lies on the dorsal line from the frons to the base of the second abdominal segment, and reaches laterally between the first and second abdominal segments nearly to the venter. This applies to the penultimate moult; the last one seems not quite so extensive a splitting.

The colour changes at ecdysis are beautiful to behold. The older nymph, on emerging, is entirely pale pink, and takes some time to acquire the metallic blue colour. Two adults emerged, one at 6.30 A. M. and the other at 3 P. M. These also were at first wholly pale rose-coloured. Then a white area, an important feature of the imaginal pattern, appeared on the pronotum and next at the tip of the scutellum. The normal colour, form, and the length of the hemielytra were achieved in two to three hours.

Nymphs in the third (?) and fifth stadia were observed in the field as late as the 18th of April (Guines). They seemed to have disappeared a month earlier in the Soledad (Cienfuegos) district.

3. THE FEEDING-HABITS OF *E. sellatus.*

This insect belongs to a subfamily known to be predominantly predaceous in habits. The closely allied *E.* (*Largus*) *succinctus* (L.) has been recorded as occasionally injurious to plants in North America.*

On the other hand Riley (*Insect Life*, vol. I, p. 130, 1888) mentioned the same insect as an enemy of *Icerya purchasi.* The Argentine *E.* (*Largus*) *rufipennis* Lap. is recorded by Jensen-Haarup (*Ent. Medd.*, Trett. Bd., pp. 222, 223, 1920) as frequenting *Senecio mendocinus.*

In Cuba the very active blue nymphs of *E. sellatus* are observed roaming over a variety of unrelated plants in an unrestricted manner reminiscent of the carnivorous members of the Pentatomidæ. Both nymphs and adults are plentiful in the cane and maize fields, especially among young cane. The food of the former was not ascertained with certainty though two examples certainly lived ten days with nothing edible but sugar-cane leaf, and were able to pass through an ecdysis successfully. An adult was seen sucking the remains of a small Embiid, and these insects were also devoured in captivity. The *Euryophthalmus* inserted its mouthparts near the posterior end of a larger Embiid, holding down the head, meanwhile, with one middle tarsus. The imago also sucks the flowers of *Chamissoa altissima* HBK.—this being the only certain case of phytophagy observed.

When this bug, in the adult stage, is handled it exudes, or in fact squirts, from the anus a quantity of dark brown liquid, but there is no appreciable odour either from this or from the scent-glands.

4. THE PRE-ADULT STAGES OF *Dysdercus andreæ* (L.).

(a) *The eggs.*—It is extraordinary how little is known of the eggs of such common and much-studied insects as the cotton-stainers. Eggs of other insects were several times ascribed to *D. suturellus*, the common North American species, before the true ones were discovered.

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*Causing some injury to cotton bolls, Sanderson, 1906, *Bur. Ent. U. S. D. A., Bull.* 57, p. 46; Glover; Mally, 1893, *U. S. D. A. Div. Ent., o. s. Bull.* 29, p. 31; Morrill, 1910, *U. S. D. A. Bur. Ent., Bull.* 86, p. 94, Pl. I, Fig. 7, text-figs. 24, 25; ibid., 1917, *Journ. Econ. Ent.*, vol. 10, p. 309; causing some injury to peaches, Lintner, 1885, *2nd Rep. N. Y. State Ent.*, p. 164, fig. 41.

A pair of *D. andreæ* was taken *in copula* on the 12th of February. In the early morning, though very lethargic with the cold, they were still *in coitu* and had apparently remained so during the night. One egg was laid on the 15th. Two other copulating pairs were captured on the 12th of March. Eggs were laid on the 15th apparently at random, eight in one lot, one by itself and five in a third mass. One male and both females died two days later. The eggs lay on the floor of the vial, adjacent ones adhering together. They appeared translucent, of a very pale greenish colour.

Alcohol examples measured 1.17 by 0.77 mm., and were almost perfectly elliptical in shape, with a highly polished, apparently quite impunctate surface, and four tiny cylindrical obtuse projections arranged in trapezoid fashion at one pole. In alcohol they appeared ivory white.

When Heidemann in 1911 published a résumé of recorded knowledge of Heteropterous eggs, those of only two Pyrrhocorid species were known. These were similar to those of Lygaeidæ, but the "chorial processes low and not narrowed towards the base." (*Proc. Ent. Soc. Wash.*, vol. 13, p. 133). Riley and Howard (*Ins. Life*, vol. I, p. 235, 1889) quote Hubbard to the effect that the eggs of *D. suturellus* H.-Sch., are oval, amber-coloured, with a pearly lustre and beneath the lens a pattern of closely reticulated lines. Morrill (*Op. cit.*, pp. 95-98, pl. I, Fig. 8) deals more fully with the same common species. He found that about 465 eggs were deposited by four females, both loosely and in masses, but little compacted.

A very good account is that of T. C. Barber, dealing with the Texan *Dysdercus obscuratus* Dist. (*Journ. Agric. Res.*, vol. 31, pp. 1137–1147, 2 Figs., 1 table 1925). Herein are recorded some truly remarkable facts connected with oviposition. The "eggs look very much like microscopic hens' eggs" and are shining pearly white, semi-transparent. They are laid singly or in small clusters adhering but slightly together. Of the five nymphal stadia the first is spent entirely underground, feeding upon a supply of decaying vegetable matter ***provided by the female at oviposition.*** Most of the second stadium is occupied in the same manner. In the laboratory the female usually buried with the eggs a piece of dead leaf or fruiting capsule of the food-plant, a species of the Malvaceous genus *Sida*. "When a suitable capsule had been selected, the female would deposit two or three eggs, then carefully cover them with soil, pulling the particles over them with her feet. More eggs would then be deposited and covered in their turn, until finally the entire capsule would be buried under the surface."

The nymphs of D. andreæ: The first instar of *D. andreæ* was not observed since my eggs failed to hatch. Descriptions from captured specimens of the succeeding instars follow:

Second instar.—Length before feeding, 2.1 mm., after feeding, 3.1 mm. Colour vivid scarlet, almost immaculate, but the lateral borders of the abdominal segments with an indistinct whitish spot, and the scent-gland orifices slightly indicated in brownish. Antennæ with a brownish tinge. The dimensions of head, thorax and appendages are stationary throughout the stadium, but with feeding, the abdomen, from being as long as head and thorax together, becomes considerably longer and much swollen, like an aphid's. In later instars the effect of feeding is less noticeable.

Third instar.—Length before feeding, 3.7 mm. This instar is at once distinguished from the preceding by the much larger head and thorax. The colour is similar, but the whitish connexivum is more extensively, though not more distinctly, marked. The postero-lateral angles of the meso- and metanotum are slightly fuscous. Only two distinct ventral teeth on the fore femora.

Fourth instar.—Length before feeding, 4.5 mm. Fore border of pronotum china white; abdomen with the connexival spots china-white and very distinct. Brownish scent-gland spots distinct. Whole latero-posterior portions of meso- and metanota blackish; tegminal pads distinctly produced, but posterior border of the metanotum still almost straight. Ventrally the coxæ and the posterior margins of the abdominal segments marked with china-white. Three ventral teeth on fore femora distinct. Rostrum reaching nearly end of 3rd abdominal segment.

Length after feeding, 5.6 mm. Markings much the same. Scent-orifices distinctly black. Rostrum reaching end of 2nd abdominal segment.

Fifth instar.—Whitish markings much accentuated, spread to the posterior margins of the dorsal abdominal segments and to that of pronotum. Wing-pads and tegminal pads black, the former bordered laterally, near apex, with yellowish white. Posterior lateral angles of pronotum slightly infuscate. Rostrum reaching end of second abdominal segment. Length, 6.8 mm.

Apparently only the advanced instars climb the food-trees, *Thespesia populnea* and *Hibiscus elatus*, the younger nymphs feeding on seeds which have dropped to the ground beneath.

5. THE PRE-ADULT STAGES OF *Dysdercus mimus* (SAY).

The eggs of this species, a more obscurely-coloured cotton-stainer than *D. andreæ*, but nearly as common, were not found. Of a pair taken *in coitu* on the 2nd of March, the female appeared swollen with eggs, but dissection showed that most of the enlarged abdomen was occupied by fat-body and digestive tract, the state of the ovaries being but little advanced. Copulating pairs of *D. andreæ*, it is perhaps worth mentioning, were sometimes found with the female's abdomen much swollen as with eggs, and sometimes perfectly flat and apparently empty.

The nymphs.—The earliest nymph found, probably the 2nd, was 2.3 mm. in length. Head dark brownish red, pronotum and abdomen pinkish scarlet, slightly marked with fuscous at the scent-glands and apex of the abdomen. Mesothorax and metathorax orange.

The next instar was 3.8 mm. long, and similar in colour but the scent-gland markings more distinct and the tegminal and wing angles fuscous.

The last instar observed, almost certainly the fifth, was 5.6 mm. long. Colour, deep orange red, the head purplish red; pronotum edged anteriorly with white; tegminal pads fuscous, edged laterally with whitish; segments of abdomen faintly marked with whitish; scent-gland orifices and apex of abdomen fuscous; ventral surface of abdomen whitish, the segments marked with red, of the thorax orange with china white at the coxæ, of head reddish.

The emerging adult was pale yellowish, with red head, black eyes and smoky membrane. The white pronotal collar so conspicuous in the hardened imago was at this stage also very distinct.

6. THE FEEDING–HABITS OF *Dysdercus*.

Considering the almost exclusively phytophagous tendencies of the Homoptera, it is remarkable how few of the Heteropterous families are wholly plant-feeding. The Cryptocerata are nearly entirely carnivorous—the Corixids forming a partial exception; the Miroid families all contain at least some predaceous forms; the Reduvioid groups are eminently predatory; while the Pentatomids and Lygaeids number very many rapacious species, and such are not lacking, as we have seen, in the Pyrrhocoridæ. Only the Coreidæ, Berytidæ, Tingidæ and probably the rather problematical Aradidæ, seem to confine themselves to plant-food.

The purely predatory families, like the Reduviids and most of the water-bugs, are highly specialized morphologically for the capture of prey, while the predaceous members of the Pentatomidæ and Lygaeidæ, belonging to families not given over wholly to this method of feeding, are considerably less so. But in the Miridæ and the Pyrrhocoridæ those forms which prey on other insects seem scarcely modified at all. In these two families notwithstanding the fact that one subfamily of the Pyrrhocorids is, as we have seen, predominantly carnivorous, while some Miridæ seem to be strictly confined to such a diet, most members of both families are chiefly or entirely phytophagous. It would appear then that the carnivorous habit is recently acquired among Mirids and Pyrrhocorids. It is possible that *Dysdercus*, which tends to be omnivorous, may throw some light on the origin of the carnivorous habit in the Pyrrhocoridæ. In developing this possibility I am dealing only with the habits of two common Cuban species—the only forms I have studied in the field. It seems, however, from the literature on cotton-stainers, that my limited studies are in accord on this point with more extensive ones made elsewhere and on other species of the genus.

There is abundant evidence that both nymphs and adults require concentrated food rich in proteins. They obtain this in quantity from the developing seeds of plants, especially of the Malvaceæ; but they do not disdain to procure it from any animal matter which they can conveniently negotiate. Their habit, described below, of feeding upon dead animal matter, or upon their live comrades while these are held by an antenna or leg in the grip of a Chelifer, is but one grade removed from that of such forms as *Euryophthalmus*, which captures insects on its own account.

Taxonomically, of course, the most striking feature in the feeding-habits of the *Dysderci* is their strong predilection for the Malvaceæ—a *penchant* which has made them serious pests almost wherever cotton is grown. Irrespective of the staple, if varied food-plants of the species, the adults congregate in large numbers upon the flowers of Compositæ and less frequently of other families, apparently to suck nectar. I have rarely found the nymphs exploiting this source, and then only the older ones. The following nectar sources were noticed:

Adults and older nymphs of *D. mimus* occurred on the flowers of *Neurolaena lobata* (L.) R. Br.; adults alone on those of *Casearia aculeata* and of *Parthenium Hysterophorus* L.

Imagines of *D. andreæ* congregated on the flowers of *Bidens* sp., of *Vernonia menthaefolia* (Poepp.) Less., of *Caseraia decandra* (Jacq.) and of *Parthenium Hysterophorus* L.

On the 21st of February, when the swarms of *D. andreæ* on *Hibiscus elatus*—a favourite food-plant of adults and nymphs—and on the flowers of *Casearia decandra* were phenomenally abundant, I was impressed by the fact that whereas nearly all the adults on the former were copulating, not a single mated pair could be found on the *Casearia* flowers. This difference of behaviour on the staple food-plant as distinct from the source of nectar seems fairly constant. No copulation of *D. andreæ* was observed on Composite flowers; but one pair of *D. mimus* was found *in coitu* on the blossoms of *Neurolaena lobata.*

During my sojourn at Soledad the staple food-plants, as distinguished from the sources of imaginal nectar supply—the mere playhouses of the adult—were few in number; but simply swarming with the insects in question.

D. andreæ occurred, in all stages, especially on *Thespesia populnea* Cav., on *Hibiscus elatus* Sw., and on *Sterculia Carthaginensis.* In much smaller numbers it was seen feeding and copulating also on *Abutilon* sp., and, at Guines only, on *Sida* sp.

D. mimus was devoted to less arboreal hosts and occurred chiefly among undergrowth and in waste places on the following Malvaceæ: *Sida* sp. (near *cordifolia*) and *Abutilon* sp. It was attached chiefly to the *Sida*, which is a common and wide-spread weed.

Majagua or *Hibiscus elatus* is a large forest tree with showy red flowers followed by stout green schizocarps. During the three months, February to April, *Dysdercus andreæ* abounded on and beneath two trees of this species in the Harvard Botanical Garden. Near the beginning of the above period the freshly opened fruits were hidden beneath scarlet masses of copulating adults, sucking the juices of the young seeds, which falling to the ground below, proved a vast attraction to the myriads of young nymphs, running in all directions over the surface and on the lower plants, but mounting no higher than a foot. No nymphs were observed on the fruits upon the tree, and the overwhelming majority were on the ground itself. Here and there were little red clusters of living bugs, chiefly nymphs, forming balls up to an inch in diameter. These centered and swirled round dropped seeds of the majagua. A sample cluster contained 82 small nymphs and 3 imagines. One adult, walking with a seed suspended from its mouthparts, carried five nymphs hanging in their turn from the same nutritious morsel. The combined weight seemed nearly to pull the older insect off the leaf. The nymphs discover isolated seeds of the food-plant with uncanny precision. A single seed, lodged in the leaf-sheath of a grass, 20 feet from the tree, had its swarming cluster of red nymphs.

It was curious that only two majagua trees, both very large, were frequented by *D. andreæ* in the Botanical Garden. A smaller tree, likewise in fruit, but situated several hundred yards away, was entirely free from this species during the three months mentioned, as also was an adjacent small tree of the very closely related *H. tiliaceus.*

A lofty majagua in the forest of the Trinidad Mountains at the Mina Carlota was attracting large numbers of *D. andreæ* on the 20th of March. A large tree of the same species in the garden of Mr. Geo. S. Scudder at Soledad was similarly frequented, the bugs constituting a household nuisance by their very numbers. Here, towards the end of April, I noticed advanced nymphal instars feeding upon the fruits on the tree itself. The younger nymphs, on the other hand, always confine their attention to seeds which have dropped to the ground, and to fallen floral parts.

Towards the end of April, when my observations were terminated by my departure, there were decidedly more late instars than any others under the two majagua trees in the Garden. The insects on the whole were as abundant as ever and adults were still largely copulating, but were scarcer.

As on majagua, so on that favourite shade tree, *Thespesia populnea* Cav., *D. andreæ* was plentiful during February to April. The greatest swarms, however, were seen during the early part of that period. Probably *Thespesia* is the host of an earlier brood than majagua, since on the 11th of February, while the *Thespesia* fruits swarmed with adults and advanced nymphs, the majagua trees showed only imagines and young nymphs. By the 3rd of March no nymphs, only copulating adults, were found in the *Thespesia* avenue, though the advanced nymphs occurred as late as the 28th beneath a tree of the same species in the Botanical Garden, possibly from the nearby majaguas.

As with *Hibiscus elatus,* so with *Thespesia,* the still juicy seeds were the prime attraction for all instars, though adults were found also on the buds. But the latter tree does not scatter isolated seeds as the former does—it drops the whole fruit. On the tree the older nymphs and the imagines attack the still green fruit, leaving droplets of hardened juice to mark their punctures. Artificial stabbing produces instant exudation of a bright yellow thickish sap, which hardens rapidly on exposure. The dried-up, hardened fruit which finally drops to the ground, looks and feels almost impossible of negotiation by the bugs. At first it contains nevertheless still juicy seeds. A tremendous cluster of bugs was assembled round a single crack in one such fruit. Such behaviour indicates that it is difficult if not impossible for the bugs to puncture the hardened fruits themselves. On the 31st of March, after heavy showers, a number of nymphs were clustered round loose seeds from fruits which had been softened by soaking. But I broke up some still intact fruits and found their seeds very hard, and apparently quite unattractive to the *Dysderci* even when left a long time in their path.

Towards the end of April I found tremendous numbers of *D. andreæ* on a large tree of *Sterculia Carthaginensis.* These were chiefly advanced nymphs, with very few adults. There were not only the familiar swirling clusters round fallen fruits, but also great patches, some 6 inches in diameter, upon the trunk and larger branches, especially at knots, insertions of branches or other irregularities in the very smooth bark of this tree. The biggest of these more or less inactive patches was at a height of about 5 feet, the next at 8 feet, above which there were very few congregated bugs. These patches were several layers deep.

Curious to relate *D. andreæ* was not found on *Sida* sp., the favourite host of *D. mimus*, at Soledad, but only near Guines, in the Havana district. There, just after a heavy shower, literal handfuls of both nymphs and adults of this and the other species were congregated in rolled, fallen leaves of pendejera (*Solanum torvum*) lodged in the *Sida* branches and to a less extent in the adjacent weeds.

On the 2nd of March *D. andreæ* imagines were found copulating on *Abutilon* sp. and sucking the unripe fruit.

There remain several less regular sources of food exploited by *D. andreæ.* Clusters are quickly formed round any of their fellows crushed on a foot-path, while examples captured and held by the Chelifers considered in the next section are soon sucked dry by their companions. The detached wing of a small bird served as a centre of attraction, though the flesh was apparently dried up. A piece of orange gathered a similar congregation. Riley and Howard (*i.c.*) record *D. suturellus* as a pest of oranges in Florida, while an anonymous contributor to the *West Indian Bulletin* (vol. 15, pp. 315–318, 1915, *Rev. Appl. Ent. Ser. A.* vol. 4, p. 432) recommends the juice of ripe oranges as the best trap for *Dysdercus.*

Advanced nymphs of *D. andreæ* formed a large part of a mixed company including ants and Diptera sucking honey-dew fallen on the wide perforate leaves of *Monstera* from Coccids in a tree above. But the nymphs do not travel far, and are thus likely to use such additional food sources only in the close vicinity of their staple food-plants.

Dysdercus mimus was plentiful in the dry dusty situations where flourished *Sida* sp. The leaves of this were frequently spotted with yellow, as in cases of bug attack, but analogy would lead one to suppose that the fruits form the chief attraction to *D. mimus*. I did not observe them sucking the leaves. On the 10th of March nymphs in nearly all stages occurred with adults in numbers in the dusty surface layers below these plants, and under flakes of cowdung and logs in the immediate vicinity.

In March especially, *D. andreæ*, together with the Coreid, *Jadera sanguinolenta* was attracted in crowds to the electric lights of the laboratory. I did not see *D. mimus* in this situation. Can this difference in behaviour be associated with the difference in feeding-habits—*D. andreæ* feeding chiefly on tall trees and the other on low-growing weeds? There were food-plants of both well within a hundred yards of the laboratory.

In the laboratory during the day it was interesting to see *D. andreæ* adults standing with outstretched rostra round a vessel of water, drinking with avidity.

7. THE NATURAL ENEMIES OF *Dysdercus*.

I am concerned in this section to give a general review of the animal enemies of *Dysdercus* spp. and to discuss in the next section the evidence for and against the theory of warning colouration as applied to these insects, and in the light of these data.

Other Arthropods.—A small ant, *Solenopsis geminata* (Fabr.) was observed dragging away a dead adult of *D. mimus* much larger than itself. A small, partly crushed nymph of *D. andreæ* was placed on a low branch in the midst of numerous passing *Pseudomyrma elongata cubaensis* Forel. Many passed by, but others demolished it in a very short time. The same species of ant was busily engaged, in considerable numbers, on a silk-bound mass of remains of *D. andreæ* hanging in the web of an

Epeira vulgaris Hentz, a spider which must thus be counted among the enemies of the adult bug.

Another Arachnid predator presented features of unusual interest. As early as the 20th of February I noticed numerous copulating adults of *D. andreæ* on the fissured bark of a *Thespesia* in the Garden. Many of these appeared dead. Later observations showed that most of the live insects in this situation were busily engaged, whether *in coitu* or single, in sucking dead examples of the same species. Elsewhere it was rare to see a dead example, but on this trunk one could always find clusters of living bugs engaged in the above manner. The victims seemed in some way fastened in crevices in the bark. In one case of a copulating pair, one member was but a dead and empty corpse, depending from the abdomen of its mate. Sometimes a live bug still *in copula* struggled ineffectually to disengage itself from a dead mate which was held prisoner in some crevice. I visualised some gummy secretion which might entangle the appendages of the bugs and detain them till their companions sucked them dry. At one spot a pair and a single bug were caught in the same crevice, both insects by the tip of an antenna. Very gently cutting away the adjacent flakes of bark, not without inadvertently freeing one of the bugs, I saw at the bottom of the crevice a gleam as of beads of my hypothetical secretion. But there was no secretion—only the shining cephalothorax of a Chelifer, still partially hidden, but holding tightly with one of its powerful pedipalpi, the antenna of the *Dysdercus*. I next dug out two other mated pairs of cotton-stainers. In one case a Chelifer was holding an antenna, in the other detaining its victim by the tip of a leg. Finally, every case investigated, every tethered bug, showed a Chelifer at the root of the matter. These Chelifers, *Chelanops oblongus* (Say) proved extremely numerous beneath the bark-flakes of this one tree. All were completely hidden during the day and all looked extremely bloated. There was no sign of the pseudoscorpions emerging to feed on their prey—all the captive bugs that I saw had been or were being sucked by cannibalistic members of the same species. But beneath the bark with the Chelifers, were numerous fragments of the Pyrrhocorids. Either the Arachnids pull under the disintegrated fragments of the insects—since there is no room for the intact bug, so very much larger than its enemy—or they emerge at night to feed on the prey secured during the day. I was not able to clear up this point. Since, however, it is quite usual to find a Chelifer holding by one appendage a *Dysdercus* which though dead and empty, is quite intact, it seems clear that the death of the victim is usually brought about by the punctures of its comrades. This is suggested also by the readiness with which a maimed or half-crushed individual is attacked. We have then an extraordinary association in which an enemy organism assists an insect to slaughter its own fellows, and is apparently content with little more than the scraps from the ensuing feast.

In Montserrat fewer than 20 percent. of *Dysdercus andreæ* and of *D. delauneyi* are attacked by a "small Arachnid" parasite (Anon., 1914). This is probably the ectoparasitic mite mentioned by Sands (1917) in St. Vincent on *D. delauneyi* Leth. Ballou (1916) records a thrips attacking eggs of the same *Dysdercus*. Among the enemies of *D. superstitiosus*, de Seabra (1920) lists a common Myrmeleonid. Tachinid parasitoids of some of the African species have been studied, but are not considered of great economic importance (Pomeroy and Golding, 1923). They are known also in Trinidad (Urich, 1916, *Trichopoda*) and in North Australia (Hill, 1915). Well-known predaceous enemies of various African *Dysderci* are Reduviids of the genus *Phonoctonus* often extraordinarily similar in appearance to the species on which they prey. Finally, Corbett (1924) records the Pyrrhocorid, *Antilochus coqueberti* (Fabr.) as preying on *D. cingulatus* (Fabr.) in Malaya. This list of Arthropod enemies of the cotton-stainers makes no claim to completeness; but it will serve for a general view.

Vertebrate enemies.—I have described above the congregation of *D. andreæ* and *D. mimus* in nearly all stages in rolled up leaves of *Solanum torvum* lodged in twigs of *Sida* at Guines. These plants were almost overhanging the waters of a small brook, abounding in tiny fishes, *Gambusia punctata* Poey. These were fed with the various stages of the two *Dysdercus* species, with the bright red and black ladybird, *Chilocorus cacti* (L.) and with numerous examples of the very brilliant, sluggish, crimson and metallic blue Lycid, *Thonalmus sauvis* (Duv.)*. All were seized and eaten with avidity; but a large

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*I am indebted to Mr. H. S. Barber, of the U. S. Bureau of Entomology, through the courtesy of Dr. L. O. Howard, for the determination of the ladybird, and to Mr. P. J. Darlington, Jnr., for that of the other beetle.

D. andreæ nymph and a smoothly polished and much rounded ladybird presented mechanical difficulties which prevented immediate seizure by the smallest fishes, and were not surmounted until a larger fish of the same species arrived with a mouth large enough to engulf them. There can be no doubt from these experiments that any of the *Dysderci* falling into the water would be speedily devoured.

A large Cuban tree-frog, *Hyla septentrionalis* Boulengar, in captivity ate numbers of *D. andreæ* at night.

Probably the most widespread, active and numerous vertebrate enemies of insects in Cuba are the lizards, which abound in species and swarm in individuals. On the 15th of March a lizard, *Anolis sagræ*, entered the laboratory building, in which were numerous specimens of *D. andreæ* attracted by the light on the previous evening. These insects were readily eaten when confined with the lizard, about a dozen being devoured in about twenty-four hours. In view of the proof, obtained at this time, that *Dysdercus* formed part of the normal diet for this species, the experiment with captured lizards was discontinued.

Observations were made on lizards under the large *Hibiscus elatus* tree frequented so much by *D. andreæ*. Two *Anolis sagræ* were feeding about the lower trunk and on the adjacent ground on the 25th of February. I was not able quite to see what they caught—it looked like ants, but was so small and was seized so quickly that I was not sure. The lizards were extremely shy and one had to remain very still to observe them at all. No instar of the Pyrrhocorids appeared to be touched. There could be no possibility of misoneismus here, for these bugs were the commonest insects in the vicinity. Four times over one lizard and twice over the other crawled a pair of adults *in copula*. In one case the insects thus engaged passed right along the back of the lizard from head to tail. One lizard made a slight scratching motion, but otherwise there was absolute indifference. On the 17th of March two lizards of the same species were caught under this tree. The stomach of one contained the remains of one *D. andreæ* nymph and of one spider; that of the second disclosed three nymphs of this species, in apparently the fourth stadium. On the 12th of April, under the same tree, a larger *Anolis sagræ*, even when evidently disturbed by my presence, snapped up an advanced nymph of *D. andreæ* which was carrying from its rostrum a seed of majagua. This seed the lizard rejected very neatly.

A larger lizard, *Leiocephalus cubensis*, was also active beneath the same tree, but was not captured for dissection, nor seen actually eating *Dysdercus*. It was much shyer and quicker than the *Anolis*.

Birds.—In spite of long vigils in early morning, beneath *Hibiscus* and *Sterculia* trees swarming with *D. andreæ*, I observed none of the common Cuban insectivorous birds feeding upon these insects. But such negative results are of but little more value than those gained by feeding birds in captivity. The remains of Heteroptera are easily recognisable in stomach-contents, and the role of birds is best ascertained by an examination of the stomachs of large series of the various species.

In Australia, Hill (1915) records *Graucalus melanops* as feeding on *Dysdercus cingulatus*. The same insect is eaten in large numbers in India by *Oriolus kundoo, O. melanocephalus, Hierococcyx varius* and *Sitta frontalis* (Mason and Maxwell-Lefroy). According to these authors and to Heikertinger orioles are especially fond of Heteroptera, including the most strongly-smelling species. Sands (1917) lists domestic fowls, *Tyrannus rostratus* and *Crotophaga ani* as enemies of *D. delauneyi* in St. Vincent. Every stomach of the *Tyrannus* examined contained large numbers. To the same list may be added *Quiscalus fortirostris* (Anon., 1919). Ballou (1918) however, considers cotton-stainers in St. Vincent as particularly free from natural enemies. Guppy (1914) too believes that, with few exceptions, birds play an insignificant part in the control of insect pests in Trinidad. He lists *Dysdercus howardi* among the insects abundant in localities where birds are plentiful. Mason (1917) found two species of *Dysdercus* in Nyasaland preyed upon in the nymphal and adult stages by *Coturnix delegorguei*, a record which recalls Csiki's discovery of no fewer than 94 examples of the European *Pyrrhocoris apterus* in the stomach of one *Perdix perdix*. Heikertinger (1922, p. 461) quotes Dahl as finding 11 specimens of a Pyrrhocorid in the stomachs of four *Cacomantis insperatus*, and numerous examples of "kleine rot und schwarz gefarbte Pyrrhocoriden" in three stomachs of *Lamprococcyx plagosus*, a second small cuckoo from the Bismarck Archipelago.

8. *Dysdercus* AND THE THEORY OF WARNING COLOURATION.

In a previous section I have described a *Sterculia* tree with its smooth grey trunk emblazoned with great bloody patches, six inches in diameter, consisting of advanced nymphs of *Dysdercus andreæ* several layers deep. The fallen fruits of the tree looked like beautiful scarlet flowers from the masses of the same insect. Similar congregations have been described on and beneath *Hibiscus elatus* and *Thespesia populnea.*

These insects make no attempt at concealment like assemblies of cryptozoic animals; their colour and behaviour renders them conspicuous throughout the day, whether individually or *en masse;* they have no apparent means of defence, whether organized or individual, passive or active, spines or sting; they depend upon a specialized and restricted food-supply and their numbers are not reinforced daily, like those of mosquitoes or of Chironomids, by new swarms from more favourable breeding grounds replete with unlimited quantities of generalised food-material. All their cards are apparently upon the table; yet their congregations persist month after month in an environment densely populated with small birds and swarming with insectivorous lizards.

Has *Dysdercus* some hidden quality, perhaps a nauseous taste, which protects it from predaceous animals and to which can be attributed the persistence of its conspicuous congregations? From the mere fact of persistence and from the absence of any more obvious means of defence, the extreme selectionist would perhaps make this assumption offhand.* If further, the conspicuous colour serves to advertise this disagreeable taste or other quality, the principle of warning colouration is in operation. But our present knowledge of insect ethology is surely not great enough to warrant this assumption unless it is strongly supported in each case by subsidiary evidence from the behaviour of insect-eating animals in the same environment.

Undoubtedly the strict relativity of food-habits stressed by a number of more recent workers, especially Swynnerton,

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*In commenting on the exhaustive treatise of Bequaert on the predaceous enemies of ants, Poulton (1924) claims that the very fact that ants are dominant insects, common and conspicuous and "advertised by their communities as well as by their appearance, ... in itself supplied the evidence of special defence that Dr. Baquaert apparently believed to be lacking."

Heikertinger and Mottram, must be kept constantly in view. Thus Mottram has shown (1918) that the nature of the prey in the case of trout and of birds depends upon the following factors.—

1. The animal's general hunger. Extremely hungry animals will eat almost anything.
2. The animal's special hunger. Trout and less certainly birds, prefer a mixed diet and may become satiated with one kind after excessive feeding upon it.
3. The relative ease of capture.
4. The prevalence of the food-supply. Trout and less certainly birds will concentrate on hunting one kind of prey at a time.
5. The palatability of the prey.

Reighard (1908) in a thoroughgoing study of brilliantly coloured coral-reef fishes, found that 21 species, when they were deprived of the shelter of their reefs, were readily eaten by common rapacious forms. He believes that the predatory species have learned all the food possibilities of their environment and possess too great a discriminative power to need warning colouration in their possible prey. "Coral fishes are not conspicuous because they are in the reefs; they are in the reefs because they are conspicuous and cannot therefore leave the reefs, and because, being in the reefs and taking the food as they do, there is no reason for their being inconspicuous." Their colours are the result of race tendency unchecked by natural selection. Applying his results to the phenomena of "warning colouration" in general, he suggested that bright colours are due to the absence of counteracting selection owing to immunity conferred:—

(a) by inaccessibility. E. g. coral-reef fishes;
(b) by distastefulness;
(c) by stings or by armour.

In practice such a theory differs but little from the orthodox hypothesis of warning colouration. In theory it is strongly divergent. It regards the discriminative powers of predatory animals as too highly developed to render advertisement necessary. That Reighard exaggerates these powers is shown by a number of recent observations and especially by those of Mottram (1918) on the deception of birds and fishes by trout-flies and even by stray pieces of vegetable matter.

Will this or the original theory of warning colouration explain the case of *Dysdercus andreæ?* On the score of inaccessibility, whether achieved by activity or by shelter, *Dysdercus* is decidedly not immune; nor is it protected by stings or armour. Distastefulness is extremely difficult to prove. It is a curious fact that a very large proportion of the more cryptically-coloured Gymnocerate Heteroptera, which are provided both as nymphs and as imagines with highly efficient and to man extremely malodorous scent-glands, are readily eaten by birds and mammals. Evidence that Heteroptera form, in fact, next to beetles, the most important food of insectivorous birds, has been assembled by Heikertinger (1922). Yet the apparently "warningly" coloured Pyrrhocoridæ seem singularly lacking in these odorous secretions.

Adults of *Dysdercus andreæ* have no perceptible odour when handled. Moreover the roughest shaking fails to cause any exudation from the dorsal glands of the nymphs. Sometimes a clear but scentless liquid was emitted at the anus. Similarly no smell was ever perceived from nymphs or adults of *D. mimus*. On the other hand, my only example of *D. sanguinarius* Stal, taken near Guines, emitted a distinct but not strong "buggy" odour. This observation perhaps needs confirmation with more material. *Dindymus sanguineus* (Fabr.), an Oriental Pyrrhocorid, is said by Kershaw and Kirkaldy (1908) to be odorless in all stadia. Heikertinger (1919, 1922) has shown that *Pyrrhocoris apterus* is practically scentless in the adult stage.

It remains to show whether distastefulness can be deduced in *Dysdercus* from the behaviour of possible predators.

We have seen that *D. andreæ* is preyed upon by several insects and Arachnids. The indiscriminate taste of most predaceous Arthropods seems, however, well established by the work of Poulton, Marshall, Heikertinger and others.

The particular fish species experimented upon—*Gambusia punctata*—ate with avidity not only *Dysdercus andreæ* and *D. mimus*, but also ladybirds and other beetles of typically "warning" colouration. But lest we conclude from this that fishes are wholly indiscriminate, we have the admirable studies of Mottram (1918) to show that English Ephemeridæ may be arranged in strict order of palatability for trout, beginning with *Ephemera danica* Mull., and ending with *Heptagenia sulfuria* Mull. The latter, brilliant yellow and the most conspicuous of British mayflies, is practically never eaten. But the habits and habitat of fishes would seem to debar them from acting as very efficient agents in the natural selection of colour and pattern in purely terrestrial insects.

We may leave our tree-frog out of the discussion. It is largely nocturnal in habits and "De noche todos los gatos son pardos." Moreover, it apparently finds *Dysdercus* as palatable as did Heikertinger's frogs and toads the related *Pyrrhocoris apterus*.

There remain the reptiles, birds and mammals, of which the latter may be left out of the question as entirely negligible under Cuban conditions. The birds are an uncertain quantity. We have not seen *Dysdercus* eaten by birds in Cuba; but in the preceding section there is collated evidence that fellow members of the genus, sharing the usually conspicuous *Dysdercus* type of colouration, are eaten at least to some extent, by some birds. Heikertinger (1919, p. 191) found *Pyrrhocoris* readily eaten by several species of birds. Moreover, as noticed above, Heteroptera in general form one of the most important items in the diet of insectivorous birds. It is true, however, that every supposed case of warning colouration should be established on its own merits, and it must therefore be admitted that possibly *Dysdercus andreæ* is entirely distasteful to Cuban birds, and owes its abundance to the comparative immunity thus acquired. In view, however, of the general evidence adduced above, this possibility must not be made a positive assumption until a thorough study of the stomach-contents of the commoner Cuban insectivorous birds has brought some supplementary evidence that these insects form no part of the normal diet.

The abundance of small lizards in Cuba is exceptional. Their numbers, their ubiquity and their agility render them probably the most important vertebrate enemies of insects in Cuba. And we have seen that *D. andreæ* forms at least a part of the normal diet of the commonest of them, *Anolis sagræ*.*

At present then, the only evidence that *Dysdercus andreæ* is distasteful and that the distastefulness is associatid with its conspicuous colouration are the facts that it *is* abundant and is conspicuous and has no more obvious means of defence.

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*The behavior of two of these lizards which allowed copulating *Dysderci* to crawl upon their bodies affords no evidence against this conclusion. In New Zealand I have repeatedly watched bluebottles, beetles, earthworms and other accepted food-animals crawl on the body of a tuatara (*Sphenodon punctatum*) or over its feet, without eliciting the slightest response, even when the animal was known to be hungry. Such behavior would seem more readily explicable in psychological than in gastronomic terms.

Heikertinger, if he admitted there were a legitimate problem in the case of *D. andreæ* at all, would perhaps suggest misoneismus as a solution, as in the case of the closely allied and similar *Pyrrhocoris apterus* (1922, 1919). This author recognizes no other experimentally valid content in the theory of warning colouration. He proved, by most ingenious experiments, that the frequent rejection of this Pyrrhocorid by various vertebrate enemies depended upon colour and form alone. Eagerly eaten, obscurely-coloured Pentatomids were avoided when painted to resemble *Pyrrhocoris* or plastered with its hemielytra. In those cases in which *Pyrrhocoris* or its imitation was eaten in the end, he ascribes the preliminary rejection to Misoneismus or distrust of the strange. In the case of *Dysdecrus*, so plentiful, so widespread and so conspicuous, this principle could scarcely conceivably operate, at least under the conditions we have described in Cuba. The only class of Cuban insect-eating vertebrates which we have not been able to demonstrate as enemies of *D. andreæ* are the birds; and these, by reason of their mobility, their ubiquity and their keen vision, are precisely the ones which are likely to be the most familiar with the appearance of such an abundant insect.

In those cases, *e. g.*, experiments with lizards, in which the *Pyrrhocoris* or its imitation was not eaten in the end, Heikertinger ascribes the total rejection to the fact that such insects do not form part of the normal diet. This conception is developed more fully in an earlier paper devoted chiefly to problems of phytophagy (1915) and enunciating the principle of taste-specialisation in the animal world. Every animal has a definite circle of organisms as nourishment. In the normal food a protection is logically unthinkable; in the other it is unnecessary. We think, however, that there is sufficient variation in the food-habits of insectivorous vertebrates to take from this principle most of its validity as a criticism of the theory of warning colouration. As an example, take the nests of termites, which, whether built of carton or hollowed in wood, are ordinarily invulnerable to small lizards. I cut open such a nest in the Cuban forest. Swarms of termites fall to the ground. In a few minutes one hears, on every side, a rustle and a patter on the dead leaves, as of an oncoming shower. Small lizards, chiefly *Anolis sagræ*, are hurrying in from every direction and from a distance of many yards. Some hop from twig to twig of the undergrowth; others scurry over the rustling leaves. One feels a light touch on the back; an *Anolis* trips lightly over one's shoulder and down one's front to the termites on the ground below. It is astonishing to see the rapidity with which the lizards assemble and the celerity with which the termites are devoured. These lizards are diurnal; the termites are ordinarly protected in their nests, and in their movements abroad are sheltered by covered run-ways. It would therefore seem that they could in no sense form part of the normal diet of the lizards, to which only accident can render them accessible. But the spectacle of a seething mass of termites in a broken nest inspires nothing akin to misoneismus in the lizards, nor do they ignore the comparatively unfamiliar food.

In conclusion, I cannot resist the temptation to report one case in which the "warning colouration" of *Dysdercus andreæ* apparently accomplished all that the theory demands. In the Trinidad Mountains, our companion in the forest one day, a member of the Rural Guard, exclaimed warningly "Pica! Pica" ("It stings! It stings! ") when I picked up an example of *D. andreæ.* Whether he mistook it for the somewhat similar Reduviid, *Zelus rubidus,* which is said (Bruner, 1926, *Mem. Soc. Cubana Hist. Nat. "Fel. Poey"*, vol. 7, p. 78) to be "capaz de producir picadas dolorosas al ser cogido", or whether he suspected such capacity from the "warning colouration" I am not sure.

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STUDIES ON THE CRANE-FLIES OF MEXICO.
PART III.*

(Order Diptera, Superfamily Tipuloidea).

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The present paper is a further contribution to our knowledge of the Mexican crane-flies. The preceding parts appeared in 1925 and 1926 (Annals Ent. Soc. America, 18: 341–362, 1925; 19: 158–179, 1926). The present instalment is based on the extensive collections made in the State of Chiapas during 1926 by my friend, Dr. Alfons Dampf, who very kindly allowed me to retain the types of the novelties. The majority of the specimens were secured in the vicinity of San Cristobal las Casas, the former capital of Chiapas (altitude 2100 meters) and on the neighboring ranges of the Zontehuitz and Moshbiquil mountains, the highest altitude at which Tipulidæ were taken being on the summit of the Zontehuitz, at an altitude of 2800 meters. Other large and representative series were secured at lower altitudes, at the Rancho Sabino Perez (altitude nearly 500 meters), Santa Lucia (altitude 575 meters) and San Isabel (altitude about 650 meters), making a notable contrast with the fauna of the high altitudes around San Cristobal. Still other collections were made at Tonala, a station on the Pan-American Railway, near the Pacific Ocean, and one of the hottest parts of the Mexican Republic (M. F. Nos. 930, 930a). The entire collection, including more than 1000 specimens, is of the greatest possible value in the unusual number of records that it includes.

The following *Mexican Biocenosis* (M. B.) and *Mexican Fauna* (M. F.) numbers of the collector require the following summary. These and all others in the series are to be made the subject of exhaustive memoirs on the Mexican fauna and flora by the distinguished collector.

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*Contribution from the Entomological Laboratory of the Massachusetts Agricultural College.

Hueitepec: Swept in the dense leafy woods covering the Hueitepec, near San Cristobal, altitude 2600 meters. M. B. 170. *Limonia ludibunda* sp. n., as well as an undescribed species of *Elephantomyia* and the most northerly species yet discovered of the *Tipula monilifera* group.

Zontehuitz: Typical dense, damp virgin forest near the summit of the Zontehuitz, altitude 2750 meters, in immense numbers between the leaves of a *Bromelia* association. M. B. 176. *Dicranomyia exœta* sp. n., *Erioptera dampfi* sp. n., *Molophilus fuscopleuralis* sp. n.

San Cristobal: Very narrow, shadowy ravine of a small mountain brook, falling in cascades from the Moshbiquil mountain to the valley of San Cristobal, arising from a spring some 75 meters higher. M. B. 190, 190a. *Gonomyia chiapasensis* sp. n., *Erioptera* (*Mesocyphona*) *apicinigra* sp. n., *E.* (*M*) *saturata* sp. n., *Molophilus obediens* sp. n., and undescribed species of *Geranomyia*, *Epiphragma* and *Atarba*, not discussed at this time.

San Isabel: Altitude about 650 meters, near a swift flowing brook; typical pine ridge vegetation; attracted by light. M. F. 1057. *Erioptera* (*Erioptera*) *quadricincta* sp.n., *E.* (*Empeda*) *stygia* sp.n., *E.* (*Mesocyphona*) *modica* sp. n., *E.* (*M.*) *leucopasta* sp. n., *Rhabdomastix* (*Rhabdomastix*) *isabella* sp. n.

Besides the novelties discussed herein, Dr. Dampf has added most materially to our knowledge of distribution of previously described forms. The most interesting feature of the Chiapas collections might be considered the unusual development of the subgenus *Mesocyphona* of *Erioptera* Meigen, no fewer than 11 species having been taken on this expedition.

In the present report and others to be published under this title, the venation of the radial field of the wing is materially changed. The detailed paper by the writer discussing this modification should be consulted (The interpretation of the radial field of the wing in the Nematocerous Diptera, with special reference to the Tipulidæ. Proc. Linn. Soc. New South Wales, 52, 1927, in press).

I wish to express my deepest thanks to Dr. Dampf for the great privilege of examining this unequalled series of Mexican Tipulidæ.

Limonia Meigen.

Limonia infucata sp. n.

General coloration orange, the praescutum with the narrow interspaces conspicuously dark brown; front silvery; antennæ brownish black throughout; halteres elongate, black; wings dark brown, *Sc* very long, Sc_2 at the tip of Sc_1; male hypopygium with the ventral dististyle an oval fleshy lobe, the rostral prolongation without the usual spines.

Male. Length about 5 mm.; wing, 7.3 mm.

Rostrum and palpi dark brown. Antennæ brownish black throughout; basal flagellar segments subglobular, becoming more elongate outwardly, the outer segments elongate-cylindrical. Front and anterior vertex silvery, the posterior vertex rufous; vertex narrow, the silvery coloration ending at the narrowest point.

Pronotum light brown, vaguely variegated with darker. Mesonotum high and gibbous. Praescutum bright orange-rufous, the interspaces appearing as narrow dark brown lines, extending from the humeral region, crossing the suture, and then appearing as narrower margins on the mesal and caudal margins of the scutal lobes; scutum and scutellum orange-rufous, the median area of the former a little paler, the caudal portions of the latter more infuscated; postnotal mediotergite obscure orange, darker laterally. Pleura testaceous yellow, indistinctly variegated by a narrow brown stripe passing from the fore coxa above the halteres, on the pleurotergite becoming more extensive. Halteres elongate, black, only the extreme base of the stem brightened. Legs with the coxæ yellow, the trochanters more obscure; remainder of legs brownish black, the femoral bases scarcely brightened; tarsi a trifle paler than the tibiæ but not evidently brightened. Wings relatively long, narrowed basally, dark brown, the stigma indicated only by a narrow seam at the end of vein R_2; veins darker brown. Venation: *Sc* very long, Sc_1 ending just before the fork of *Rs*, Sc_2 at its tip; *Rs* long, subangulate at origin; basal section of R_2 relatively short; distal section of R_1 longer; R_{2+3} about two-thirds R_3; cell *1st* M_2 short-rectangular; *m-cu* shortly before the fork of *M*, subequal to the distal section of Cu_1; cell *2nd A* relatively narrow, vein *2nd A* being gently sinuous.

Abdominal tergites dark brown, the sternites obscure brownish yellow; hypopygium and segment eight somewhat paler. Male hypopygium with the ventral dististyle appearing as a relatively small oval fleshy lobe, the rostral prolongation conspicuous, nearly glabrous, provided with a few setæ but without the usual spines; before apex on outer margin with a small pale triangular flange.

Holotype, ♂, east of San Cristobal, swept from bushes in dense forest of oaks and pines, altitude 2250 meters, July 7, 1926 (A. M. Dampf); M. B. 186.

Limonia perflaveola sp. n.

Male. Length about 3.5 mm.; wing, 4.5 mm.

Very closely allied to *L. alfaroi* (Alex.), of which it may perhaps prove only a variety, differing especially in the shorter subcosta.

Antennal flagellum pale brown. Remainder of body entirely pale yellow, the mesonotum a little more reddish yellow. Wings with the stigmal spot oval, distinct but pale; *Sc* relatively short, Sc_1 ending before midlength of *Rs*, in most cases at near one-third the length of this vein; in most specimens a series of macrotrichiæ on the distal third of vein *2nd A*.

Holotype, ♂, Cerro San Cristobal, June 29, 1926 (A. M. Dampf); M. F. 1005.

Paratopotype, ♂, June 30, 1926; M. F. 1007; paratype, ♂, San Cristobal, June 4, 1926; M. F. 940.

Limonia ludibunda sp. n.

Thoracic praescutum reddish yellow with three dark brown stripes; head black with a silvery-white longitudinal line; pleura dark with a pale longitudinal stripe; wings brownish yellow with a heavy brown pattern, *Sc* relatively short, ending just beyond the origin of *Rs*.

Male. Length about 6 mm.; wing, 7.3 mm.

Rostrum and palpi black. Antennæ black throughout, the basal flagellar segments short-oval, with short pedicels, the outer segments becoming more elongate-oval. Front and the narrow anterior vertex pure silvery-white, the coloration extended caudad onto the posterior vertex as a similar narrow line to the occiput, the remainder of the posterior vertex and occiput black.

Pronotum yellow, dark laterally. Mesonotal praescutum reddish yellow with three dark brown stripes, the humeral region and broad lateral margins of the sclerite yellow; scutum dark brown, the lateral margins of the lobes narrowly yellow, the median area, the scutellum and the postnotum black, sparsely dusted with gray. Pleura dark brown dorsally, restrictedly paler brown on the ventral sternopleurite, the two enclosing a broad pale longitudinal stripe that extends from behind the fore coxa to the meron, the surface sparsely pruinose. Halteres pale, the knobs dark brown. Legs with the coxæ and trochanters brownish yellow; femora brown, their bases more yellowish, the tips passing into dark brown; tibiæ dark brown, the tips and the tarsi black. Wings relatively long and narrow; membrane with a brownish yellow suffusion, clearer yellow before and beyond the origin of *Rs*, in the outer end of cell *M*, and the ground-color of the cells beyond the cord; stigma, a large spot at origin of *Rs* and end of vein *Sc*, the cord and outer end of cell *1st* M_2, and conspicuous marginal spots at ends of veins M_3, M_4, Cu_1 and the Anal veins dark brown; distal portions of cells R_2 and R_3 conspicuously suffused with paler brown; veins brown, paler in the cream-colored areas, darker where traversing the brown spots. Venation: *Sc* relatively short, Sc_1 ending at about opposite one-fourth to one-fifth the length of *Rs*, Sc_2 not far from its tip and likewise beyond the origin of *Rs; Rs* relatively short, angulated and weakly spurred at origin; inner end of cell R_3 lying proximad of cell *1st* M_2, the latter cell about as long as vein M_{1+2} beyond it; *m-cu* at the fork of *M*, subequal to the distal section of Cu_1; vein *2nd A* relatively long and gently sinuous.

Adominal tergites dark brownish black, the basal segments a little variegated baso-laterally with obscure yellow; sternites black, the first segment yellow; basal sternites narrowly ringed caudally with yellow; ventral dististyle of hypopygium pale. Male hypopygium with the ventro-mesal lobe of the basistyle very stout and sessile, terminating in a small apical papilla. Ventral dististyle smaller than the basistyle, deeply split apically into two parts, that bearing the rostral prolongation very broad, approximately equal in area to the remainder of the style; the actual beak-like portion is small, the usual two spines far removed from the rostrum, lying on the face of the lobe near its end, surrounded by a group of short delicate setæ.

Holotype, ♂, Hueitepec, in dense leafy woods, altitude 2600 meters, June 14, 1926 (A. M. Dampf); M. B. 170.

Limonia ludibunda bears a superficial resemblance to *Dicranomyia osterhouti* Alex. and *D. translucida* Alex. (Panama), but is a very distinct fly.

Dicranomyia Stephens.

Dicranomyia exæta sp. n.

General coloration dark brown; front silvery; wings tinged with brown, the stigma darker brown, preceded and followed by a paler area; *Sc* short, Sc_2 close to the tip of Sc_1; *Rs* angulated and weakly spurred at origin.

Male. Length about 4.5 mm.; wing, 5.5 mm.

Rostrum and palpi black. Antennæ black throughout; flagellar segments oval, more elongate outwardly. Head with the front and anterior vertex silvery-white; posterior vertex light gray with a blackish area on either side.

Pronotum dark brown, the scutellum obscure yellow. Mesonotal praescutum shiny dark reddish brown with three darker brown stripes that are only a little darker than the ground-color, the humeral region obscure yellow; remainder of mesonotum dark brown, sparsely pruinose. Pleura dark brown, the dorsal portion of the sternopleurite extensively paler to produce a short, broad, longitudinal stripe. Halteres dark, the base of the stem narrowly obscure yellow. Legs with the fore coxæ dark, the other coxæ more yellowish testaceous; trochanters yellowish testaceous; femora yellow, the tips broadly infuscated; tibiæ and tarsi dark brown. Wings with rather strong brownish tinge, the stigma brown, especially near the transverse veins; paler cream-colored areas before and beyond the stigma and in the anal region; small and scarcely evident brown seams at end of *Sc* and origin of *Rs*; veins brown, the obliterative portions before the cord extensive. Macrotrichiæ of veins relatively conspicuous. Venation: *Sc* short, both Sc_1 and Sc_2 ending just before the origin of *Rs*; *Rs* angulated and weakly spurred at origin; distal section of R_1 short, nearly in alignment with the basal section of R_2, *r* being very short and the distal section of R_2 entirely atrophied; inner end of cell R_3 lying far proximad of the other elements of the cord; cell *1st* M_2 subrectangular; *m-cu* at the fork of *M*, longer than the distal section of Cu_1.

Abdomen dark brown, the sternites only a little paler; hypopygium with the ventral dististyle pale. Male hypopygium with the ventromesal lobe of the basistyle very short and sessile, terminating in a weak apical tubercle. Ventral dististyle much as in *Limonia ludibunda* sp. n., being split apically into two subequal portions, the mesal one of which bears the rostral prolongation; the spines located on the face of this mesal lobule, one spine gently curved, the other more nearly straight.

Holotype, ♂, near summit of the Zontehuitz, in dense, damp virgin forest, altitude 2750 meters, June 20, 1926 (A. M. Dampf); M. B. 176.

Dicranomyia exæta is not greatly different from *Limonia ludibunda* sp. n., especially in the peculiar structure of the male hypopygium. The two species furnish an interesting example of the insufficient grounds on which the genera *Limonia* and *Dicranomyia* are now being maintained as distinct.

Gonomyia Meigen.

Gonomyia (Gonomyia) **chiapasensis** sp. n.

Allied to *G.* (*G.*) *æqualis* Alex. (Guatemala); rostrum obscure yellow; thoracic dorsum dark gray, the scutellum yellow; pleura blue-gray with a whitish yellow longitudinal stripe; halteres elongate; wings with a strong dusky tinge; male hypopygium with the dististyle bifid, the longest arm terminating in a simple black point.

Male. Length about 5 mm.; wing, 6 mm.

Female. Length about 5–5.2 mm.; wing, 6 mm.

Rostrum obscure yellow, a little darker dorsally; palpi black. Antennæ black throughout. Head dark gray.

Pronotum gray, the anterior lateral pretergites sulphur-yellow, narrowly interrupted by a dark spot before the wing-root. Mesonotum dark gray, the praescutum with three very slightly darker brown stripes; pseudosutural foveæ black; scutum dark gray, the median region a little paler; scutellum conspicuously yellow, darker medially at base; postnotum dark, dusted with gray, the cephalic lateral region narrowly yellowish. Pleura blue-gray with a conspicuous whitish yellow longitudinal stripe, extending from behind the fore coxa, on the pteropleurite becoming somewhat more yellowish and including the whole sclerite; pleurotergite gray; dorsopleural membrane largely sulphur-yellow. Halteres elongate, brown, the base of the stem pale. Legs with the coxæ dark gray, their lower faces brown; trochanters dark brown, paler beneath; remainder of legs dark brown, the bases of the femora paler. Wings with a strong dusky tinge, the stigma slightly darker, oval; veins dark brown. Venation: Sc_1 ending opposite or just beyond the origin of *Rs*, Sc_2 very variable in position, sometimes at the tip of Sc_1, more often removed from this tip, in extreme cases Sc_1 alone being only a little shorter than *m-cu*; petiole of cell R_3 elongate, subequal to or only a little shorter than R_4; cell *1st* M_2 elongate-rectangular, gently widened outwardly; *m-cu* a little less than its own length beyond the fork of *M;* anterior arculus lacking.

Abdominal tergites dark brown, the sternites and hypopygium obscure yellow. Male hypopygium generally similar to *G.* (*G.*) *æqualis* Alex.; outer fleshy lobe of the basistyle relatively slender, dark-colored, the small, triangular lobe at base relatively conspicuous; dististyle bifid, one arm forming a dusky rounded knob that terminates in about a dozen setæ of various sizes, the other arm narrowed outwardly, the tip a simple slender black point with the tip obtuse. In *æqualis* this tip is bifid. Aedeagus and gonapophyses much as in *æqualis*, the subterminal spine of the former long and slender.

Holotype, ♂, San Cristobal, altitude 2100 meters, June 4, 1926 (A. M. Dampf); M. F. 940.

Allotype, ♀, near San Cristobal, July 17, 1926; M. B. 190a.

Paratypes, 5 ♂♂, with the allotype.

Gonomyia (Lipophleps) **maya** sp. n.

Belongs to the *manca* group; head and rostrum orange; antennæ entirely dark; thoracic pleura with a faint silvery longitudinal stripe; wings with the stigma barely indicated; male hypopygium with the dististyle simple, fleshy, unarmed, terminating in a single powerful fasciculate seta.

Male. Length about 3.3 mm.; wing, 3.7 mm.

Rostrum orange, the palpi black. Antennæ dark brown throughout; flagellar verticils elongate, as in the males of this subgenus. Head orange, the vertex behind infuscated.

Pronotum yellowish, darker medially; anterior lateral pretergites and antero-lateral margins of the praescutum bright sulphur-yellow. Mesonotal praescutum light brown, sparsely dusted with gray; median area of scutum broadly obscure yellow; scutellum brown, broadly margined caudally with yellowish; postnotum chiefly pale reddish brown. Pleura reddish brown, with a broad silvery longitudinal area beginning behind the fore coxa, passing beneath the halteres; dorsopleural region dark. Halteres brownish testaceous, the knobs obscure brownish yellow. Legs with the coxæ and trochanters reddish testaceous; femora obscure brownish yellow, passing into dark brown on the outer half; tibiæ and basitarsi light brown, the tips darker brown;

remainder of tarsi dark brown. Wings relatively broad, with a rather strong brownish tinge, the costal region clearer yellow; stigma very pale brown, scarcely evident against the dark ground-color; veins pale brown. Venation: Sc_1 ending a short distance before the origin of *Rs*, the distance shorter than *m-cu;* cell *1st* M_2 closed; *m-cu* close to the fork of *M*.

Abdominal tergites light brown, the sternites yellow; male hypopygium yellowish. Hypopygium much as in *G.* (*L.*) *manca* (O. S.), the basistyle long and slender, with a single small fleshy dististyle that terminates in a single very powerful fasciculate seta; besides this, the dististyle bears three bristles of medium size and three smaller ones on the mesal face. Gonapophyses asymmetrical, entirely pale, the longest with the basal half or more a broad flattened plate that narrows abruptly into a spinous tail-like portion, this latter narrowed gradually to the acute spinous tip; the smaller apophysis is a stout, flattened, sickle-shaped blade. Aedeagus long and slender, approximately as long as the basistyles, narrowed very gradually to the acute tip.

Holotype, ♂, San Isabel, altitude about 650 meters, July 30, 1926 (A. M. Dampf); M. F. 1057. See additional ecological notes at beginning of this report.

Paratopotype, ♂.

Teucholabis Osten Sacken.

Teucholabis dampfi sp. n.

General coloration shiny coal-black; pronotum obscure yellow; knobs of the halteres orange; two silvery areas on the thoracic pleura; wings subhyaline; stigma subcircular, dark brown; a narrow pale brown seam on the anterior cord; abdomen black.

Male. Length, 5–6 mm.; wing, 5.8 – 7 mm.

Rostrum and palpi black. Antennæ black throughout; flagellar segments short-oval. Head shiny black.

Pronotum obscure yellow, the scutellum and pretergites black. Mesonotum shiny coal-black, the scutellum a trifle paler. Pleura black, with two conspicuous paler areas that are covered with a dense microscopic silvery pubescence, one area on the dorsal portion of the sternopleurite, the other on the meron; dorso-pleural membrane dark.

Halteres dark, the knobs conspicuously orange. Legs with the fore coxæ obscure yellow, the anterior face darkened; remaining coxæ obscure yellow; trochanters yellow, the tips darkened; femora obscure yellow, the tips blackened, broadest on the fore femora where the distal two-thirds or more is included, much narrower on the middle and hind femora; fore tibiæ black, middle and hind tibiæ brownish yellow, the tips narrowly blackened; tarsi brownish black. Wings subhyaline; stigma subcircular, dark brown; a paler brown seam on the anterior cord and a similar vague wash at near midlength of cells *M*, *Cu* and *1st A;* veins black. Venation: *Sc* relatively short, Sc_1 ending about opposite one-third to two-fifths the length of *Rs*, Sc_2 variable in position, in cases removed from the tip of Sc_1, in others closer to this tip; R_{2+3+4} short to virtually obliterated; basal section of R_2 oblique in position, about equal to R_{1+2}; cell *1st* M_2 elongate; ***m-cu*** close to the fork of *M;* vein ***2nd A*** nearly straight. In some cases, Sc_2 is atrophied.

Abdomen black, including the hypopygium; in some specimens the bases of the sternites narrowly paler.

Holotype, ♂, summit of one of the mountains of the Moshbiquil range, altitude 2500 meters, in pine forest, July 17, 1926 (A. M. Dampf); M. F. 1033.

Paratopotypes, 15 ♂♂.

The types were found swarming about five feet above the ground.

Teucholabis dampfi is named in honor of the collector, Dr. Dampf, who has added so vastly to our knowledge of the insects of Mexico. It is readily distinguished by the diagnostic features as given above. By means of the writer's key to the American species of the genus (Trans. Amer. Ent. Soc., 40: 235–239; 1914), the species runs out at couplet 14.

Erioptera Meigen.

Erioptera (Empeda) **stygia** sp. n.

Size very small (wing, ♂, 3 mm. or less); general coloration brownish black; wings strongly suffused with blackish; *Sc* short, veins R_3 and R_4 divergent.

Male. Length about 2–2.4 mm.; wing, 2.5–3 mm.

Rostrum and palpi dark brown. Antennæ brownish black throughout. Head dark brown.

Thorax entirely brownish black. Halteres brownish black, the basal third of the stem paler. Legs with the coxæ and trochanters brown; remainder of legs dark brown. Wings strongly suffused with blackish, the stigma scarcely darker; veins dark brown. Venation: *Sc* very short, Sc_1 ending just beyond the origin of *Rs*, Sc_2 somewhat removed from its tip, exactly opposite this origin; R_{2+3+4} a trifle longer than the basal section of R_2; R_{3+4} straight, longer than R_3; R_3 and R_4 strongly divergent, R_3 being oblique in position, cell R_3 at margin being more than twice as wide as cell R_2; petiole of cell M_3 shorter than ***m-cu***, the latter at the fork of *M*.

Abdomen brownish black, the hypopygium a trifle paler.

Holotype, ♂, San Isabel, altitude about 650 meters, July 30, 1926 (A. M. Dampf); M. F. 1057. Additional ecological notes given at the beginning of this report.

Paratopotype, ♂.

E. (*E.*) *stygia* is one of the smallest species of *Empeda* so far described.

Erioptera (Empeda) **oresitropha** sp. n.

General coloration dark gray; wings cream-colored, the base and costal region brighter; stigma conspicuous, dark brown; paler brown clouds on the cord and along vein *Cu* in cell *M;* wing-apex a little suffused with dusky.

Male. Length about 4 mm.; wing, 5 mm.

Rostrum and palpi black. Antennæ black throughout. Head brownish gray.

Pronotum dark gray, yellowish laterally. Mesonotal praescutum dark gray, without stripes; antero-lateral pretergites narrowly sulphur-yellow; humeral triangles paler than the ground-color; pseudosutural foveæ black. Pleura dark gray, the region of the wing-base ochreous. Halteres obscure yellow, the knobs dark brown. Legs with the coxæ and trochanters brown; femora brownish black; tibiæ brown, the tips narrowly darker; tarsi brownish black. Wings cream-colored, cells *C* and *Sc* and the wing-base more yellowish; stigma oval, dark brown; distinct paler brown clouds along the cord and vein *Cu*, the latter almost covering the distal half of cell *M;* wing-apex more or less suffused with dusky; veins pale, much darker in the clouded areas. Venation: *Sc* long, Sc_1 ending about opposite three-fifths the length of the long *Rs*, Sc_2 faint, far from the tip of Sc_1, the latter alone about equal to *r-m;* basal deflection of R_2 shorter than R_{2+3+4}; veins R_3 and R_4 generally parallel to one another, cell R_2 at margin being only a little narrower than cell R_3; petiole of cell M_3 about equal to *m-cu*, the latter at the fork of *M*.

Abdomen brownish black, including the hypopygium. Male hypopygium with the apex of the basistyle a little produced. Outer dististyle strongly bifid, the outer arm shorter, its apex expanded. Inner dististyle gently curved, a little expanded outwardly, the surface with a few scattered setulæ.

Holotype, ♂, Summit of the Zontehuitz, north of San Cristobal, altitude 2800 meters, swept from low bushes, *Baccharis* and *Gaultheria*, June 20, 1926 (A. M. Dampf); M. B. 174.

E. (*E.*) *oresitropha* is generally similar to the larger *E.* (*E.*) *alticola* Alex., differing conspicuously in the wing-pattern, the longer and more evident macrotrichiæ of the wing-veins and the details of venation.

Erioptera (Erioptera) **quadricincta** sp. n.

Allied to *E.* (*E.*) *annulipes* Will.; tibiæ with four dark and four white annuli, the first dark ring narrowest and basal in position; vein *2nd A* sinuous, the apex simple.

Male. Length, 2.8–3 mm.; wing, 2.8–3 mm.

Female. Length about 3.3 mm.; wing, 3–3.1 mm.

Rostrum and palpi brownish black. Antennal scape brownish black, the flagellum paler, especially the basal segments. Head clear light gray.

Mesonotal praescutum pale grayish brown to yellowish brown, brighter brown laterally, the interspaces narrowly darker and provided with a row of conspicuous dark setæ; posterior sclerites pale. Pleura pale brown with a narrow silvery longitudinal stripe extending from behind the fore coxæ, passing beneath the root of the halteres. Halteres pale, the stem before the knob a little darkened. Legs with the coxæ and trochanters testaceous; femora testaceous yellow at base, the remainder white with four brown to brownish black rings, the first paler and sometimes more poorly indicated, the remaining annuli increasing in size outwardly, the white inter-rings narrow, the extreme tip white; tibiæ white with four brownish black rings, the first narrowest, at the base of the segment, the others alternating with narrower white rings, on the posterior tibiæ the light and dark annuli subequal in area, the apical ring white; basitarsi with the basal third and apical third black, the central third white; second tarsal segment white; remainder of the tarsi black, forming the third dark tarsal ring; the femora thus appear to have four dark rings, of which the first may be more or less indistinct, the tibiæ four rings, the first narrow and basal in position, the tarsi with three dark rings, of which two are on the basitarsi. Wings grayish yellow, with marginal dark spots at the ends of the veins, alternating with white spots in the ends of the cells, the white areas more extensive than the dark; veins yellow, darker in the infuscated areas; Sc_2 and the cord brownish black. Venation: ***m-cu*** in alignment with ***r-m***, some distance beyond the fork of *M;* vein *2nd A* sinuous, the tip simple.

Abdomen pale brown, the hypopygium yellow.

Habitat: Mexico, Guatemala.

Holotype, ♂, San Isabel, Chiapas, altitude about 650 meters, July 30, 1926 (A. M. Dampf); M. F. 1057.

Allotype, ♀, Tonala, May 23, 1926; M. F. 930a.

Paratopotypes, several ♂ ♀ ; *paratypes*, ♀ , with the allotype; ♂ ♀ , Santa Lucia, Chiapas, altitude 575 meters, July 29, 1926; M. F. 1055; ♂ ♀ , Rancho Sabino Perez, altitude nearly 500 meters, July 28, 1926; M. F. 1052; ♂, Aguna, Guatemala, altitude 2000 feet, (Dr. G. Eisen).

Erioptera (Erioptera) **dampfi** sp n

General coloration ochreous; wings pale yellowish subhyaline, the veins pale; male hypopygium with the outer dististyle deeply bifid, the arms slender; gonapophyses appearing as long slender rods.

Male. Length about 4–4.2 mm.; wing, 5–5.2 mm.

Female. Length about 4.5 mm.; wing, 5.8–6 mm.

Rostrum ochreous; palpi dark brown. Antennæ brownish black, in some cases the terminal segments of the flagellum a little paler. Head ochreous.

Thorax pale ochreous yellow, in cases with a faint brownish tinge, the lateral pretergites and lateral margins of the sclerite whitish yellow;

pseudosutural foveæ pale. Pleura brownish testaceous, the sternopleurite and ventral pleurotergite paler, more yellowish to form a vague longitudinal stripe. Halteres pale, the knobs a little darker. Legs with the coxæ and trochanters obscure yellow, the fore coxæ darker; remainder of legs yellow, the terminal tarsal segments darker. Wings pale yellowish subhyaline, the veins and trichiæ only a little darker. Venation: R_{2+3+4} about twice the basal section of R_5; cell M_2 open; vein *2nd A* relatively short, ending before midlength of *Rs*, only the distal fourth or less sinuous.

Abdomen dark brown, the hypopygium a little paler. Male hypopygium with the outer dististyle deeply bifid, the arms slender, the inner arm about one-half longer than the outer, forming a gently curved black spine. Inner dististyle broader at base, near midlength narrowed into a gently curved sinuous spine. Gonapophyses appearing as long, slender, nearly straight pale rods, lying generally parallel to one another.

Holotype, ♂, near summit of the Zontehuitz, in dense, damp virgin forest, in immense numbers between the leaves of a *Bromelia* association, altitude 2750 meters, June 20, 1926. (A. M. Dampf); M. B. 176.

Allotopotype, ♀.

Paratopotypes, 30 ♂ ♀.

This very interesting *Erioptera* is dedicated to the collector, Dr. Alfons Dampf, to whom I am vastly indebted for many favors.

Erioptera (Mesocyphona) **saturata** sp. n.

Male. Length about 3 mm.; wing, 3.8–3.9 mm.

Female. Length about 3.8 mm.; wing, 4.8 mm.

Generally similar to *E.* (*M.*) *eiseni* Alex., differing especially in the darker coloration of the body, the dark wings with the white spotted pattern more contrasted, the conspicuous black subterminal ring of the femur, and especially the structure of the male hypopygium.

Mesonotal praescutum with the stripes more grayish than yellowish, the interspaces and lateral margins black. Legs with the femora yellow, with a broad black subterminal ring, about one-half wider than the pale apex, the yellow coloration before and beyond this ring somewhat paler than the remainder of the femur; fore femora with a much narrower additional black premedian ring; tips of the tibiæ narrowly and weakly infuscated but scarcely blackened; basitarsus yellow, the tip and remainder of the tarsi dark brown. Wings with the ground-color much darker than in *eiseni*; costal margin more yellowish, especially basally; the white pattern arranged as in *eiseni* but appearing more contrasted against this darker background; spots at ends of veins R_{1+2} and R_3 widely separated.

Male hypopygium with the outer dististyle strongly bifid, as in the subgenus, but the inner arm stout and weakly split at apex into two short divergent points; inner dististyle broad at base, the distal half markedly narrowed and strongly sickle-shaped. Gonapophyses flattened, relatively broad, the tips obliquely truncated.

Holotype, ♂, near San Cristobal, in shaded ravine of mountain brook, altitude nearly 2200 meters, July 17, 1926. (A. M. Dampf); M. B. 190 a.
Allotopotype, ♀.
Paratopotypes, 2 ♂♂.

Erioptera (Mesocyphona) **apicinigra** sp. n.

Male. Length about 2.8 mm.; wing, 3.6 mm.

Generally similar to *E.* (*M.*) *eiseni* Alex., differing especially in the broad blackened apices of the femora and the structure of the male hypopygium.

Mesonotal praescutum with the stripes more grayish than yellowish, the interspaces black, the lateral margins narrower and paler. Legs with the femoral tips broadly blackened, on the posterior legs including more than the distal fifth; posterior femora with a still broader median black ring, the two enclosing a narrow subterminal yellow annulus; tips of the tibiæ infuscated but not blackened; basal two tarsal segments yellow, their tips and the remainder of the tarsi infuscated. Fore legs broken. Wings with the costal half much darker than the posterior half, the spots large and contrasted; costal margin almost uniformly dark; no white spots in the anal cells except those at the ends of the veins.

Male hypopygium as in *eiseni*, the arms of the outer dististyle and the inner dististyle all very slender and heavily blackened, the tips acute and simple, very gently curved; inner dististyle without scattered setæ, as in *eiseni*. Gonapophyses long and slender, the two taken together appearing lyriform, the extreme tips very weakly expanded, pale, obtuse.

Holotype, ♂, near San Cristobal, in shaded ravine of mountain brook, altitude nearly 2200 meters, July 17, 1926 (A. M. Dampf); M. B. 190 a.

Erioptera (Mesocyphona) **leucopasta** sp. n.

Male. Length about 2.5 mm.; wing, 2.9 mm.
Female. Length about 3 mm.; wing, 3.2 mm.

Somewhat resembling in its general appearance, a small specimen of *E.* (*M.*) *eiseni* Alex., differing in the wing and leg coloration and, especially, in the structure of the male hypopygium.

Praescutal stripes broad, restricting the dark brown interspaces. Legs with the femora yellow, with a conspicuous brownish black ring close to the tip, the apex beyond it scarcely one-fourth the length of this ring, white; a similar narrow whitish ring precedes the dark annulus; no premedial dark ring on fore femur; tip of tibiæ narrowly but conspicuously dark brown; tarsi pale yellow, the terminal two segments and the tips of the others brown. Wings with a conspicuous dark brownish ground coloration that is only slightly paler in the posterior cells; wing-spots numerous and small; a series of about six such spots along the costa in the space beyond *h* and including the end of vein R_{1+2}; the other marginal white spots are likewise small; the marks along the cord and the other white areas of the disk similarly restricted; veins dark, white in the pale areas.

Male hypopygium of very distinct structure. Outer dististyle profoundly bifid, the basal portion including only about one-fourth the total maximum length of the style; outer arm a straight slender smooth spine; inner arm longer, the basal half or a little more stouter, the outer margin with a series of five or six irregular teeth, the long apex a straight acute spine. Inner dististyle a flattened pale blade, at the widest point about one-fourth the length, the base very narrowly constricted, the outer margin densely fringed with long yellow setæ. Gonapophyses dark, the tips blackened, at about two-thirds their length strongly curved mesad toward one another, their tips subacute.

Holotype, ♂, San Isabel, altitude about 650 meters, July 30, 1926 (A. M. Dampf); M. F. 1057.

Allotoptype, ♀.

Paratopotype, ♀.

Erioptera (Mesocyphona) **modica** sp n

Male. Length about 1.8 mm.; wing, 2.3 mm.

Female. Length about 2.2 mm.; wing, 2.7–2.8 mm.

Very similar to *E.* (*M.*) *invariegata* Alex. (Amazonian Peru) in the unmarked wings and uniformly darkened legs, differing in certain minor details, as the uniformly pale halteres. The discovery of the male sex of *invariegata* will surely furnish genitalic differences.

Antennal flagellum paler than the scape. Scutellum pale testaceous. Halteres uniformly pale yellow. Male hypopygium with the dististyles long and conspicuous, the outer style a long straight rod, at about two-thirds the length angularly bent and narrowed to a long acute apical spine. Inner dististyle about as long, firmly fused with the outer style or arm, the tip expanded, bifid, the large outer arm truncated, its surface microscopically roughened, the slender subapical arm appearing as a pale straight rod. Gonapophyses appearing as elongate decussate rods, black, narrowed gradually to the acute tips.

Holotype, ♂, Santa Lucia, altitude 575 meters, July 29, 1926 (A. M. Dampf); M. F. 1055.

Allotopotype, ♀.

Paratopotypes, ♂ ♀; *paratypes*, ♂ ♀, San Isabel, July 30, 1926; M. F. 1057; ♂, between Santa Lucia and San Isabel, July 30, 1926; M. F. 1056; ♀, Rancho Sabino Perez, altitude nearly 500 meters, in hilly country, July 28, 1926; M. F. 1052.

Rhabdomastix Skuse.

Rhabdomastix (Rhabdomastix) **isabella** sp. n.

Antennæ (♂) approximately four times as long as the body; mesonotum brown, the pleura darker brown; wings brownish gray, the stigma darker; *Rs* relatively short, R_3 oblique in position, remote from the tip of R_{1+2}.

Male. Length about 5 mm.; wing, 5.2 mm.; antenna about 21 mm.

Rostrum obscure yellow, the palpi brown. Antennæ (♂) elongate, about four times as long as the entire body; scapal segments dark brown, the flagellum yellow, the outer segments darker; first flagellar segment about one-third longer than the second, the succeeding segments becoming more elongated and attenuated, the extreme tips of the individual segments dark. Head brown.

Pronotum and mesonotum uniformly rather dark brown, the surface subnitidous; scutellum yellowish testaceous; postnotum dark, paler laterally and at base. Pleura dark brown, darker than the notum; meron large. Halteres pale. Legs with the coxæ brown; trochanters elongate, brownish testaceous; remainder of the legs broken. Wings with a brownish gray suffusion, the costal region somewhat darker; stigma still darker brown; veins dark brown. Venation: *Rs* relatively short, less than two times the petiole of cell R_3; R_3 short and oblique, at margin remote from R_{1+2}, the distance on costa between them about twice R_3 alone.

Abdomen yellowish brown, darker laterally; hypopygium lighter brown.

Holotype, ♂, San Isabel, altitude about 650 meters, July 30, 1926 (A. M. Dampf); M. F. 1057. The additional data on the conditions under which the above collections were made, at beginning of the present paper, should be consulted.

R. (*R.*) *isabella* is the most northern representative of the subgenus so far discovered. It is most closely allied to *R.* (*R.*) *septentrionalis* Alex. (Costa Rica), differing in the still smaller size, the different thoracic coloration, and the distinct venation of the radial field.

Cryptolabis Osten Sacken.

Cryptolabis (Cryptolabis) **luteiceps** sp. n.

Head light ochre-yellow; thoracic dorsum dark brown; pleura dark, with a longitudinal yellow marking; tips of femora and tibiæ infuscated; wings with *Rs* short and very strongly convex.

Male. Length about 2.7 mm.; wing, 3–3.1 mm.

Female. Length about 2.6–2.8 mm.; wing, 3.2–3.6 mm.

Rostrum obscure yellow; palpi brown. Antennæ with the scapal segments brown; flagellum pale brownish testaceous; flagellar segments short-oval to subcylindrical, decreasing in size outwardly. Head light ochre-yellow.

Pronotum obscure yellow; lateral pretergites narrowly clearer yellow. Mesonotal praescutum testaceous with three confluent dark brown stripes, the extreme lateral margin of the sclerite obscure yellow; scutellum large, brownish testaceous; postnotum darker. Pleura dark, with an obscure yellow longitudinal mark on the sterno-pleurite. Halteres obscure yellow, the knobs whitish. Legs with the coxæ and trochanters testaceous yellow; femora yellow, the tips infuscated; basitarsi obscure yellow, the tips and remainder of the tarsi brown. Wings whitish subhyaline, the veins darker. Macrotrichiæ of the cells sparse, present in all cells beyond the level of cell R_2. Venation: *sc* relatively long, Sc_1 ending opposite or beyond two-thirds the length of the very strongly convex Rs; basal section of R_2 oblique to subtransverse, about equal to R_{2+3}; veins R_3 and R_4 with the tips deflected gently toward the cephalic margin of the wing; veins M_{1+2}, M_3 and M_4 similarly deflected toward the caudal margin; cell M_3 deep, its petiole very short; cell M_4 relatively short and wide.

Abdomen brown, darker in the females, this presumably caused by the presence of eggs within; terminal segments more yellowish.

Holotype, ♂, Tonala, attracted to light between 7 and 8 P. M., on the shores of a small clear rivulet flowing over pebbles and stones, May 23, 1926 (A. M. Dampf); M. F. 930a.

Allotopotype, ♀.

Paratopotypes, 3 ♀♀.

C. (*C.*) *luteiceps* is readily told by the coloration of the head.

Molophilus Curtis.

Molophilus obediens sp. n.

Belongs to the *plagiatus* group; general coloration dark brown; mesonotal praescutum ochreous, with three brown stripes, the lateral stripes occupying the margin of the sclerite between the pseudosutural foveaæ and the transverse suture; male hypopygium with the basal dististyle a powerful black spine with a smaller, curved lateral spine shortly beyond the base.

Male. Length, 3.2–3.5 mm.; wing, 4.3–5 mm.

Rostrum and palpi brownish black. Antennæ short, black throughout. Head grayish brown.

Pronotum dark, obscure yellow behind, the anterior lateral pretergite yellow. Mesonotal praescutum ochreous, with three conspicuous brown stripes, the broad median stripe darker in front, somewhat paler behind, the lateral stripes occupying the extreme lateral margins of the sclerite behind the pseudosutural foveæ; the interspaces and concolorous humeral region are thus unusually wide; in some specimens, the dark stripes are broader, restricting the interspaces, which are then cut by the pseudosutural foveæ; in still other specimens, only the humeral region of the sclerite remains of the ground-color; scutum pale, each lobe with two darker spots, the median region a little suffused;

scutellum and postnotum dark brown. Pleura dark brown. Halteres with the stem brown, the bases narrowly obscure yellow, the knobs obscure yellow. Legs with the coxæ and trochanters brownish testaceous, the fore coxæ darker; femora and tibiæ brownish yellow, with dark setæ; tarsi brown. Wings with a grayish suffusion, the stigmal region, relatively conspicuous; macrotrichiæ dark. Venation: R_{4+5} subequal to twice as long as the basal section of R_5; R_{2+3} about one-half longer than *m-cu;* petiole of cell M_3 between two and three times *m-cu;* vein *2nd A* relatively long, only gently sinuous, ending about opposite one-fourth the length of the petiole of cell M_3.

Abdomen, including the hypopygium, dark brown. Male hypopygium with the basal dististyle broad and powerful at base, on outer margin shortly beyond the base with a curved thumb-like spine, the long axis beyond this point gently curved to the acute tip, the mesal margin weakly roughened. Basistyle with the apical beak relatively slender.

Holotype, ♂, near San Cristobal, in shaded ravine of mountain brook, altitude nearly 2200 meters, July 17, 1926 (A. M. Dampf); M. B. 190 a.

Paratopotypes, 5 ♂ ♂; *paratypes,* ♂ ♂, San Cristobal, June 4, 1926; M. F. 940; June 15, 1926; M. F. 973.

Molophilus fuscopleuralis sp. n.

Belongs to the *plagiatus* group; thoracic notum reddish brown, the postnotum and pleura dark brown; male hypopygium with the basal dististyle a powerful chitinized rod, bearing a spinulose branch on outer face before midlength, the main spine with a long dense brush of black setæ along the mesal face.

Male. Length about 4.2–4.3 mm.; wing, 5.5 mm.

Rostrum and palpi brownish black. Antennæ brown, the second scapal segment darker; flagellar segments elongate-oval, covered with a dense erect white pubescence. Head dark blackish gray.

Mesonotal praescutum pale ochres to reddish brown, without distinct darker stripes, the posterior sclerites somewhat darker; postnotum dark, sparsely pruinose. Pleura entirely dark brown, contrasting with the paler praescutum. Halteres obscure yellow, the stem beyond the base darker. Legs with the coxæ and trochanters dark brown; remainder of the legs dark brown, with dark setæ, the terminal tarsal segments passing into brownish black. Wings with a strong yellow tinge, the veins pale brown; macrotrichiæ dark brown. Venation: Cells beyond the cord deep; petiole of cell M_3 a little shorter than the basal section of M_{1+2} and nearly three times *m-cu;* vein *2nd A* gently sinuous, ending about opposite one-fourth the length of the petiole of cell M_3.

Abdomen, including the hypopygium, dark brown. Male hypopygium with the spine near apex of basistyle slender. Basal dististyle a powerful chitinized rod, before midlength on outer face with a strong lateral spine that is weakly spinulose; the main axis of the style is gently narrowed to the acute tip, the mesal face from about opposite the level of the lateral spine almost to the apex with a dense brush of long black setæ.

Holotype, ♂, near summit of the Zontehuitz, in dense, damp virgin forest, altitude 2750 meters, June 20, 1926 (A. M. Dampf); M. B. 176.

Paratopotype, ♂.

Molophilus pennatus sp. n.

Belongs to the *plagiatus* group; general coloration of the mesonotum reddish brown, the pleura dark brown; antennæ (♂) relatively long; male hypopygium with the basal dististyle an elongate simple rod, the mesal face densely fringed with long setæ and scattered black spines.

Male. Length about 4 mm.; wing, 4.8–5.2 mm.

Rostrum and palpi black. Antennæ relatively long, in the male, if bent backward, extending about to the base of the abdomen, brownish black throughout; flagellar segments elongate-oval. Head dark.

Pronotum dark, the scutellum testaceous; lateral pretergites yellow. Mesonotal praescutum pale, with three reddish brown stripes that are confluent or virtually so, the humeral region and lateral margins yellowish; pseudosutural foveæ not conspicuous against this nearly concolorous background; scutal lobes reddish brown; scutellum testaceous, darker medially at base; postnotum reddish brown, the dorsal portion darker. Pleura dark brown; the sterno-pleurite ventrally paler in color. Halteres pale, the knobs yellow. Legs with the coxæ and trochanters yellowish testaceous; remainder of legs brown, with dark setæ, the tarsi passing into brownish black. Wings with a strong grayish yellow tinge, the base and costal region clearer yellow; veins darker yellow, with brown macrotrichiæ. Venation: R_{2+3} longer than the petiole of cell M_3, the latter about twice *m-cu;* vein *2nd A* elongate, gently sinuous, ending about opposite midlength of the petiole of cell M_3.

Abdomen dark brown, the hypopygium conspicuously yellowish. Male hypopygium large and conspicuous. Basal dististyle a very elongate simple rod, the basal fifth straight, beyond this point gradually narrowed and gently arcuate, the mesal face of the curved portion being densely provided with abundant setæ and subappressed stout black spines; apex of the style a stout black spine.

Holotype, ♂, San Cristobal, altitude 2100 meters, at light, June 8, 1926 (A. M. Dampf); M. F. 950.

Paratopotypes, ♂ ♂; June 8, 1926; M. F. 952; ♂ ♂, June 15, 1926; M. F. 973.

M. pennatus is most closely allied to *M. orion* Alex. (Costa Rica), from which it differs in the general coloration, structure of the antennae and the more elongate basal dististyle of the male hypopygium.

STUDIES ON THE POLYHEDRAL DISEASES OF INSECTS DUE TO FILTERABLE VIRUSES.*

R. W. GLASER, SC. D.

INTRODUCTION.

The so-called polyhedral affections of insects are extremely interesting and economically important diseases, and much has been written upon the subject. They have been described in many different larvæ. However, cases described from forms other than those belonging to the Lepidoptera are questionable. These maladies are widespread among the moth larvæ of America, Europe, Asia, and probably elsewhere, and affect many of our worst pests, producing at times huge epidemics amongst them. Such epidemics, when they occur, contribute much more towards the control of certain of our noxious caterpillars than the combined efforts of all their hymenopterous and dipterous parasites. J. W. Chapman and the writer (1), in 1915 and 1916, listed twenty-two species, belonging to ten separate families, that are definitely known to be naturally susceptible to one of the polyhedral maladies. A useful form, the silkworm, is also unfortunately subject to one of these affections. The silk industry in certain regions suffers annually due to its ravages and no satisfactory practical remedy for it's control has yet been devised.

Paillot (2), in 1926, gave an excellent review of all the literature to date, so the present article will concern itself primarily with those more recent works that have a direct bearing on certain questions still perplexing. The most important matters emphasized by J. W. Chapman and the writer (3) in their work on the wilt of gipsy moth and tent caterpillars, army worms and other species may be summarized:

1. The polyhedral diseases occur in many widely different species of lepidopterous larvæ.
2. They are highly infectious and often produce huge epidemics.
3. They are characterized by a rapid postmortem lysis of all the tissues.

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4. They are identified by curious nuclear changes occurring within certain cells, especially within the hypodermal, tracheal matrix, fat and blood cells. These changes are accompanied by the intranuclear development of the so-called polyhedral bodies, which are later liberated into the blood on the disintegration of the cells.

5. Due to the fact that these well defined nuclear changes also occur in certain blood cells, the blood is a fairly reliable index of conditions in the other tissues, and can be used for diagnostic purposes as well as for a study of the progress of the disease.

6. The infectious agent is a filterable virus. This virus easily passes through Berkefeld "N" candles. It is difficult to pass through Berkefeld "W" candles and cannot be passed through Pasteur-Chamberland "F" filters.

7. Berkefeld filtrates are free from bacteria and polyhedral bodies.

8. The polyhedral bodies vary in size and shape in different species; they vary greatly in size within one species and even within a single individual.

9. Evidence, based on the filtration experiments, on staining reactions and on certain other chemical and physical tests, was advanced to show that the polyhedral bodies must be regarded as nucleoprotein reaction or byproducts of the disease.

10. Infection naturally occurs through the mouth by means of the food, but the disease can also be experimentally reproduced through inoculation.

11. The incubation period varies, but is generally of longer duration than is the case with bacterial infections in insects, and temperature bears an important relation to this variation.

12. Certain individuals, although infected, do not acquire the disease—they are immune.

So many chronic carriers of wilt exist among our gipsy moths, that Chapman and the writer finally resorted to breeding and selection from healthy cultures to produce a disease-free race for experimental purposes. This method proved more satisfactory than others, as a comparison between our experimentally infected and control animals showed. However, gipsy moth wilt is so prevalent in New England that by using all conceivable precautions, spontaneous cases appeared in our stock and in our controls. The appearance of spontaneous cases among controls and the ruination of apparently well executed experiments is an old question, well known to European and American workers in this subject. Our results of that time were therefore subject to certain reserves of interpretation, the foregoing summary representing rather a set of tentatively formulated opinions than final conclusions.

Acqua (4) confirmed our filtration experiments in principle, using the grasserie or "jaundice" virus of silkworms instead of the gipsy moth wilt virus.

Aoki and Chigasaki (5) in some experiments with grasserie claimed that polyhedral bodies shaken in physiological salt solution, and centrifuged more than ten times were just as infectious for silkworms as the unwashed bodies. The entire work of these authors is devoted to proving that the polyhedra are parasitic.

Komarek and Breindl (6) in some work on the "Wipfelkrankheit" of nun moth larvæ came to the conclusion that the polyhedra are not the actual parasites, but that the etiological agent resides within them. These workers believe that the bodies are to be compared with galls and like them are produced as a specific reaction against the stimulation of the causative agent. The virus also exists free and as such is able to pass through Berkefeld filters.

Paillot (2,7) found that grasserie silkworm blood, freed from cellular elements and polyhedra by centrifugation and filtration through three layers of filter paper was virulent. He also discovered that he could initiate grasserie by inoculating healthy worms with the blood of worms infected two days previously and in which no polyhedra could be detected at that time.

It thus appears that our conception that the disease is due to a virus separable from the polyhedral bodies and filterable through Berkefeld N filters has been amply confirmed. There still appear to be many unsolved problems in connection with this interesting group of diseases and work with them has been continued with the following questions particularly in mind.

1. Since the polyhedral diseases of insects are caused by filterable viruses, what is the essential nature of any particular virus; where is it localized in the body and can it be seen?
2. What is the nature of the polyhedral bodies?
3. Is a particular virus specific for a particular host or not? In other words, does more than one type of virus exist?
4. Do infected females sometimes survive, and do any of these transmit the virus to the next generation through their eggs?

To answer some of these questions tent caterpillars (*Malacosoma americana*) and silkworms (*Bombyx mori*) were employed. Tent wilt occurs naturally in the region where these experiments were conducted, but it was not very prevalent during the seasons of 1923, 1924, 1925, and 1926. For this reason, it was not difficult to find healthy material for experimental purposes. Silkworm grasserie was obtained from France in 1924, through the kindness of Prof. A. Paillot. The writer had reared large numbers of silkworms for other studies during 1922 and 1923 without encountering a single case of grasserie. The first cases ever seen by him were those produced with Prof. Paillot's material. Therefore, it can be safely assumed that the stock, from which we drew our animals for the experiments, was entirely free from polyhedral infection. By the use of suitable precautionary measures, it has been possible to keep this stock free from spontaneous grasserie up to the present time.

Filtration Experiments.

Table I, page 323, represents infection experiments performed on tent caterpillars. The infectious material was derived from a single typical case of polyhedral disease found in the field. The tissues of the wilted larva were completely lysed and polyhedral bodies were abundant in the light brown liquid which oozed forth on rupturing the skin. This larva did not emit an offensive odor and stained films from some of the material did not reveal any bacteria. 0.5 cc. of this liquid from the dead larva was diluted with 5 cc. of sterile, distilled water and fed to four, 4th stage, healthy tent larvæ by smearing the material on apple leaves. The blood of these animals, prior to infection, was carefully examined for the presence of polyhedra in the nuclei of the blood cells, to eliminate the possibility of natural wilt. This precaution was taken with all the *Malacosoma* experiments in spite of the fact that only larvæ from disease-free nests were chosen.

As represented in Table I, Experiment 1, the four infected larvæ died of typical wilt in from 8–9 days. The body fluid from one of the dead larvæ was expressed and diluted in 50 cc. of sterile water. This material was passed through paper and then through a sterile Berkefeld "N" candle. The Berkefeld filtrate was tested on a variety of media for sterility and then fed to ten tent larvæ. Ten controls were held, fed with the same filtrate heated at 60°C. for 30 minutes. Experiment 2 records the results. Among those fed virulent filtrate, 8 died in the larval and 1 in the pupal stage in from 7–17 days. One lived and transformed into a moth. All of the controls lived and transformed into adults.

Experiments 3 and 4 constitute a continuation of the series, the infections produced with an individual dead of wilt in the preceding experiment. One control died of the disease in Experiment 3. This individual must have become infected accidentally during the course of the experiments. Deaths from "other causes" are also recorded in Experiments 3 and 4. These were all bacterial in nature. Experiment 5 represents infections produced by inoculating 0.1 cc. of the filtrate, prepared with physiological saline, under the skin.

TABLE I.

TENT LARVAE EXPERIMENTS.

Exp. No.	No. of Tent Larvæ	Treatment	Larvæ Died of Wilt	Pupæ Died of Wilt	Died of Other Causes	Lived and Transformed to Moths	No. of days from Infection to Death
1	4	Fed emulsified tent wilt cadaver	4				8-9
2	10	Fed Berkefeld filtrate.	8	1		1	7-17
	10	Fed Berkefeld filtrate heated 60°C. 30 minutes.				10	
3	20	Fed emulsified tent wilt cadaver	14	5	1		4-10
	20	Fed emulsified tent wilt cadaver heated 60°C. 30 minutes.	1		2	17	
4	15	Fed Berkefeld filtrate.	11	1	3		7-10
	15	Fed Berkefeld filtrate heated 60°C. 30 minutes.			1	14	
5	10	Inoc. Berkefeld filtrate.	6		2	2	9-14
	10	Inoc. Berkefeld filtrate heated 60°C. 30 minutes.			3	7	
6	10	Fed Berkefeld filtrate centrifuged 4 hr. 2,000 R. P. M., top layer.	5	2		3	8-18
	10	Fed Berkefeld filtrate centrifuged 4 hr. 2,000 R. P. M., bottom layer.	5	1		4	8-16
7	10	Fed emulsified silkworm grasserie cadavers.			2	8	
8	10	Fed emulsified silkworm grasserie cadavers.				10	
9	10	Inoc. grasserie Berkefeld filtrate.			2	8	
10	10	Inoc. grasserie Berkefeld filtrate.			3	7	
11	10	Fed emulsified gypsy wilt cadavers.			3	7	
12	10	Inoc. gypsy wilt Berkefeld filtrate.			1	9	

Experiment 6 was performed to see if the virus could be concentrated by centrifuging. A Berkefeld filtrate was centrifuged for 4 hours at 2,000 R.P.M., after which ten larvæ were fed with the top layer and ten with the bottom layer. No significant difference in virulence was observed. In all the experiments the minimum period from infection to death was 4 and the maximum 18 days. The average length of this period, about 10 days, is considerably more prolonged than is the case with the bacterial infections of insects. This fact was also recorded by Paillot (2) in 1926.

Experiments 1 to 5 inclusive, Table II, represent a series of infections in silkworms produced with Prof. Paillot's grasserie material. Experiment 1 was performed for the purpose of producing a quantity of material. A tube of grasserie blood, still containing cellular blood elements and polyhedra, was received in shipment from France. This blood was sterile for bacteria and was diluted five times with physiological saline solution and 0.1 cc. inoculated into each of 20 worms. After about 3 days a few of the worms began to show the characteristic jaundiced appearance (yellow discoloration of the white skin), and the first death occurred in 5 days.

Subsequently 11 more worms and 3 pupæ died typically of grasserie while 3 transformed into moths. Two died from the immediate effects of the inoculation. From one of these worms a Berkefeld "N" filtrate was produced as outlined in the experiments with tent wilt, and Experiment 2 performed. The series was continued to Experiment 5 inclusive. In the experiments dealing with infection by feeding, the virus was prepared with sterile, distilled water and smeared on mulberry leaves; in the inoculation experiments sterile physiological saline solution was substituted, and 0.1 cc. inoculated subcutaneously.

By consulting Table II it will be seen that no controls died of grasserie; most of the grasserie deaths occurred in the larval, a few in the pupal stage. The "other cause" deaths were due to the direct effects of the inoculation. During the inoculation of such creatures as insect larvæ, it was often impossible to avoid puncturing the gut, although a small needle was used and great precaution exercised. Most of the bacterial deaths can be traced to this source. It is shown in the table that although the worms were either inoculated or fed virulent virus, a certain proportion resisted infection and transformed to adults. This transformation into adults, of a certain number of infected larvæ, was also noticed in the experiments with the tent caterpillar virus. In the grasserie experiments the minimum period from infection to death was 5 and the maximum 24 days. The average length of this period approximately corresponds to that given for the tent wilt experiments.

Portions of all Berkefeld filtrates, employed in the tent caterpillar and silkworm infection experiments, were plated out on various laboratory media and used only when these remained entirely sterile. Furthermore, portions of the filtrates were always centrifuged and the upper layer, as well as the bottom sediment, examined microscopically in the stained and unstained condition. No bacteria or polyhedral bodies were revealed, nor was anything else seen that one could interpret with certainty as having any etiological significance. Under the dark field illumination, with high magnifications, many minute, dancing granules were observed in the Berkefeld

TABLE II.

SILKWORM EXPERIMENTS.

Exp. No.	No. of Silkworms	Treatment	Worms Died of Grasserie	Pupæ Died of Grasserie	Died of Other Causes	Lived and Transformed to Moths	No. of days from Infection to Death
1	20	Inoculated with grasserie blood.	12	3	2	3	5–16
2	20	Inoculated with Berkefeld filtrate.	14	1	1	4	6–20
	20	Inoculated with Berkefeld filtrate heated 60°C. 30 min.			3	17	
3	15	Inoculated with Berkefeld filtrate.	11	2		2	6–19
	15	Inoculated with Berkefeld filtrate heated 60°C. 30 min.			1	14	
4	15	Fed Berkefeld filtrate.	9	1		5	14–24
	15	Fed Berkefeld filtrate heated 60°C. 30 min.				15	
5	15	Fed Berkefeld filtrate.	12	2		1	12–20
	15	Fed Berkefeld filtrate heated 60°C. 30 min.				15	
6	10	Fed emulsified tent wilt cadavers.			2	8	
7	10	Fed emulsified tent wilt cadavers.			1	9	
8	10	Inoculated with tent wilt Berkefeld filtrate.			1	9	
9	10	Inoculated with tent wilt Berkefeld filtrate.			1	9	
10	10	Fed emulsified gypsy wilt cadavers.			3	7	
11	10	Inoculated with gypsy wilt Berkefeld filtrate.			1 (and 1 escaped)	8	

remained entirely sterile. Furthermore, portions of the filtrates were always centrifuged and the upper layer, as well as the bottom sediment, examined microscopically in the stained and unstained condition. No bacteria or polyhedral bodies were revealed, nor was anything else seen that one could interpret with certainty as having any etiological significance. Under the dark field illumination, with high magnifications, many minute, dancing granules were observed in the Berkefeld filtrates. Similar minute dancing granules, under similar circumstances, were also seen by the writer (3) in 1915 in his work on gipsy moth wilt. Apparently the same granules can often be seen free in the lymph of diseased caterpillars or worms and within the cytoplasm of pathological cells; especially within the nucleus during the earlier phases of the disease. These identical granules do not appear in the lymph nor within the cells of normal animals. Naturally it is difficult to decide what they are, but the writer is not impressed with their etiological significance and is inclined to believe that they constitute products of cellular disintegration.

The greatest number of filtration experiments were performed with the grade "N" Berkefeld filtrates. However, experiments were also undertaken with the grades "V" and "W" candles and with the Pasteur-Chamberland "F" filter. No lethal difference was noticed between the "V" and "N" filtrates. However, out of 20 silkworms and 20 tent larvæ inoculated with their respective viruses passed through "W" filters, only 4 tent larvæ and 1 silkworm died of disease. Twenty tent larvæ and 20 silkworms inoculated with filtrates of their respective viruses passed through Pasteur-Chamberland "F" filters lived and transformed. All the filtrations were performed at a pressure of 74 mm.

From the experiments performed on tent caterpillars and silkworms, one is justified in concluding that the viruses of tent wilt and grasserie are easily fiterable through Berkefeld "V" and "N" candles. They can be filtered through "W" candles only with difficulty, and cannot be passed through Pasteur-Chamberland filters. These results may depend upon the size or formation of the filter pores; upon the flexibility or rigidity of the virus particles; upon the electrical charge, or upon some other factor. The virulent filtrates are free from polyhedral bodies, bacteria, or any other formed body which can at present be made microscopically visible.*

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*The classification of filters is the one given in the Arthur H. Thomas Company, Philadelphia, 1926 catalog. *Berkefeld filters:* "W," fine; "N," medium; "V," coarse. *Pasteur-Chamberland filters:* "F," coarse texture and suitable for ordinary filtrations; "B," fine and suitable only for pressure.

Experiments with Washed and Fragmented Polyhedra.

J. W. Chapman and the writer (1, 3), in work on the wilt of gipsy moth larvæ, emphasized the fact that the polyhedral bodies are of great diagnostic value, but are not etiologically related to the disease. This opinion was based on positive results of certain filtration experiments which excluded the polyhedral, on the microscopical appearance of these bodies, their staining reactions, and on their physical and chemical nature. However, the work of Aoki and Chigasaki (5) and of Komarek and Breindl (6) again enveloped the above opinion in doubt. As previously mentioned, the two Japanese workers did much to attempt to prove that the polyhedra are parasitic. Komarek and Breindl claimed that the virus resides within these bodies. For this reason two further experiments were undertaken.

At separate times, two lots of polyhedral material were prepared; one was derived from a large number of tent wilt cadavers; the other from silkworm grasserie cadavers. All of the larvæ used had been dead only 3 days and on death were immediately placed on ice, to inhibit bacterial development. It is well known that the intestinal flora of herbivorous larvæ is extremely low unless a bacterial disease prevails. In each case, after enough material had accumulated, the dead larvæ were crushed in a mortar with physiological salt solution. This was then passed through cheesecloth, diluted a little more, and forced through a hard, fine pored paper (Whatman No. 50) by means of suction. The filtrate which abounded in cellular debris and polyhedra was then washed with physiological saline solution and centrifuged repeatedly, 20 times in the case of the tent and 22 times in the case of the silkworm material. This process extended over approximately 5 days, and during the interval between each cleansing process, the sediment was held on ice. After this, when it was thought that most of the virus had been removed, the final bottom sediment obtained had the gross appearance of white chalk, and on microscopic examination consisted almost entirely of polyhedral bodies, including a few urate and other crystals. The bottom sediment, which in each case amounted to about a gram of polyhedra, was shaken up with 5 cc. of physiological salt solution. 0.1 cc. of this milky white liquid was injected into each of 20 larvæ.

Twenty tent larvæ were injected with the wilt polyhedra suspension, and 20 silkworms with the grasserie polyhedra suspension. Out of the entire 40 larvæ so infected, 7 died of a bacterial septicemia and 33 transformed into moths. The blood of all inoculated worms was examined twice during the course of the experiment, at an interval of one week, but polyhedra were never seen in the plasma nor within the nuclei of the cells.

The above experiment was repeated the following year with the exception that pains were taken to fragment most of the polyhedra by grinding in a mortar. This process was followed microscopically. Further fragmentation can be obtained by pressing them between two glass panes. Twenty tent larvæ and 20 silkworms were again injected with their respective polyhedra. Thirteen died of bacterial septicemia and 27 transformed into moths. Blood examinations undertaken, as previously, were entirely negative.

It seems to us that the experiments described, when taken in conjuction with the filtration experiments, are an aid in eliminating the possibility that the polyhedra are parasitic or that they enclose a parasite.

THE HISTO- AND CYTOPATHOLOGY OF THE POLYHEDRAL DISEASES.

The Polyhedral Bodies, Their Origin and Development.—The pathological changes occurring within the tissues of insect larvæ suffering from polyhedral disease have been frequently described. The most detailed descriptions, with the technical procedures involved, are those of Escherich and Miyajima (8) in their work on Wipfelkrankheit of nun moth caterpillars, of Glaser (3) in work with gipsy moth larvæ, of Prowazek (9) and Paillot (2) in studies on grasserie of silkworms. However, to understand the subject properly, it is necessary to again outline the principal features, incorporating those more recent detailed additions to our knowledge of the histopathology of the polyhedral affections. The histopathology of these diseases, as in so many diseases of humans and other animals, is intimately associated with diagnosis. For this reason alone, an accurate picture of the visible changes occurring within the tissues is necessary. The histopathology varies very little in different species, however, and we will confine ourselves to a discussion of the course of events in the two forms under consideration—the silkworm and the tent caterpillar. The histological technique employed was similar to that given in the work on gipsy moth wilt.

Diseased silkworms usually become jaundiced a few days before death and cease to eat. Tent larvæ show few recognizable external symptoms excepting loss of appetite. On death and shortly after both forms assume a shiny brownish color, are entirely flaccid and without any offensive odor. The cadavers are extremely difficult to remove without rupturing the skin and liberating the liquid contents. This is due to the fact that a few hours after death all of the tissues are in a state of disorganization. If a film from the milky fluid of a silkworm or the brown liquid of a tent larva is examined microscopically, it will be found to contain the elements of disorganized tissues and myriads of polyhedral bodies of various sizes. In the silkworm the average polyhedra measure from 3–5μ in diameter, although individuals have been found as small as $\frac{1}{2}\mu$ and as large as 15μ. The tent wilt polyhedra are smaller, the average measuring about 2μ. They occur singly or in pairs, are very refractive and superficially resemble crystals. By manipulating the slide and cover slip, the bodies can be turned over, so that excellent views of all their faces can be obtained. Their shape varies as does their size and in silkworms 5, 6, 7, 8, and more faces are common. The corners are sharp and angular. In the smaller tent bodies the form is that of a polyhedron, with more or less rounded angles. They never assume the shape of a perfect sphere. As mentioned, the bodies are highly refractive, and on focusing seem to show a denser center differentiated from a somewhat lighter peripheral mass. Often, within the bodies, concentric layers like those of an onion are observable, demonstrating that development by accretion occurs. When pressure is applied, the polyhedra crack very readily into a number of pieces and often without the application of pressure the same fragmentation may be observed to occur somewhat more slowly. In the latter case a notch appears at one side of the polyhedron, which gradually lengthens into a line progressing slowly toward the other side, much like the cracking of ice. Usually, before the line has completely separated the two halves, other cracks appear, and soon the entire polyhedron is divided into a number of pieces, which may separate or stick together in a rosette-like fashion. The bodies have been carefully observed during the process of fragmentation, but nothing has ever been seen to escape from them. Fat globules and urate crystals have been confused with polyhedra by the inexperienced. However, the fat drops are perfectly spherical, stain with Sudan III and are soluble in ether. Polyhedra do not stain with Sudan III and are insoluble in ether. The urate and other crystals are of a totally different form, frquently show radiating lines, and react in their own characteristic manner.

A stained film of a worm, dead of grasserie or wilt, reveals polyhedral bodies, fat drops, urates and other crystals, cellular debris, hairs, setæ, food particles, and pigment granules. The pigment granules, so plentiful in a pigmented form like the tent caterpillar, must not be confused with bacteria, to which they bear a superficial resenblance. As a matter of fact, a film from a larva recently dead is almost devoid of bacteria, and in many cases none can be found. If present, the larva has been dead for some time and bacteria have entered through various channels.

The polyhedra are very resistant towards stains in general, and usually color along the periphery only, unless the stain is applied for a long time following a mordant, or some rather drastic method is applied such as steaming with carbol fuchsin. When they react, they stain uniformly, or they may show structures that simulate small refractive granules and striations. The dark field reveals these granulations very well within the polyhedra. However, as previously mentioned, nothing escapes when the bodies are fragmented that could be correlated with the etiology of the disease.

The polyhedra are heavier than water, and consequently can be obtained in bulk by centrifuging aqueous emulsions of diseased material. By repeated washing and centrifuging, the fat and cellular debris, etc., can be eliminated and the bodies obtained in a fairly clean condition. They do not dissolve in hot or cold water, alcohol, ether, or chloroform, but are soluble in strong solutions of acids and weak solutions of alkalies when boiled in them. They do not blacken with osmic acid and do not color with Sudan III, and therefore contain no fat. Picric acid stains them yellow, showing that they contain protein material. In 1916, J. W. Chapman and the writer (1) found that the gipsy moth polyhedra meet all of the requirements of the nucleoproteins and regarded them as nucleoprotein crystal-like degeneration products of the disease. No further chemical work on these bodies was undertaken. Moreover, it does not seem likely that a more accurate chemical analysis of the bodies would throw any light on the problem.

Owing to the fact that dead larvæ disintegrate completely, living diseased material must be relied upon for sectioning. By infecting a large number of individuals and fixing one every few days, all stages of the disease can be obtained.

The most striking changes occur within the nuclei of the affected cells. If the untreated nuclei, of fat or blood cells, in early cases of the disease are carefully examined, many minute violently dancing granules may be seen within. In 1915 (1), similar dancing granules were observed and described, and at that time regarded as either particles of degenerating chromatic and achromatic material or minute microorganisms. One finds such tiny granules in fresh films of all grasserie material whether dead or alive. They can readily be distinguished from pigment and other normal granules chiefly by their smaller size and greater vibration amplitude. Sections of diseased nuclei, prepared according to the method of Giemsa, demonstrate these little granules which stain red, are either single or double, and resemble tiny micrococci. Naturally, it is difficult to definitely decide the nature of these tiny particles, but the writer is now inclined to believe that they are degeneration products. The following experiment may be suggestive.

Tissue cultures of normal silkworm fat and blood cells were prepared on depression slides, under sterile conditions, using silkworm serum or Ringer's solution as a medium. These slides were held for two or three weeks, after which time various degrees of cellular degeneration of all the fat and some blood cells were obtained. Those blood cells placed near the periphery of the cover slip showed growth; they often multiplied and formed syncytia. This is a reaction produced under the influence of oxygen which filters through the thin layer of vaseline, as shown in 1918 (10). Within these normally multiplying blood cells, vibrating granules were not seen. However, all of the degenerating fat and blood cells showed minute, vibrating particles within the cytoplasm and nuclei indistinguishable from those seen in grasserie material. When fixed and stained, many of them seem morphologically identical to the granules found in disease. The writer does not offer this as absolute proof that the granules under the two different conditions are identical, but merely wishes to imply that when normal cells are permitted to degenerate they also demonstrate minute, violently vibrating granules.

In the normal silkworm and tent larval cell, the nucleus contains small round grains of chromatin distributed throughout the mass. The nucleoli are quite large and numerous; according to Paillot they always exceed ten in number within fat cells. Within the cytoplasm, according to this writer, the chondriome (mitochondria collectively) is represented by filaments distributed between the fat vacuoles.

Sections show that the polyhedra originate within the nuclei of the hypodermal, fat, tracheal matrix and certain blood cells. They are not found within the nuclei of the other tissue cells. The first indication of a diseased cell seems to be represented by a fusion of the chromatin grains and nucleoli. These form a large, dense, highly chromatophilic mass. This mass becomes speckled with minute, refractive bodies which Paillot believes originate from the chromatin grains. Within the clear area, left vacant by the condensation of the nuclear material, Giemsa's method demonstrates many little granules which bear a close resemblance to the dancing particles observed in the fresh preparations previously mentioned. Later, out of the clear nuclear zone, the polyhedra arise as very small individuals. At this stage the borders of the bodies are often faintly outlined by any stain used. As the inclusions increase in size, they become more and more refractive, do not stain at all finally, and the nucleous swells to an enormous size, sometimes measuring three times, or more, the diameter of the normal nucleus. This hypertrophy is due to the progressive increase in size of the inclusion bodies which simply fill the entire nucleus. All the polyhedra are in the same stage of development within an individual nucleus, but enormous differences in development occur between those of different nuclei. The small formative polyhedra are somewhat rounder than the larger individuals, which can partially be accounted for by the fact that, as the polyhedra grow, they become closely packed and press upon one another thus producing faces and angles. As the bodies grow and become more refractive, the little dispersed granules as well as the remains of the chromatin lump disappear and finally nothing remains but the nuclear membrane enclosing the polyhedra. Sometimes a portion of the chromatic mass persists till the nucleus disintegrates, but most frequently it vanishes before this event. Naturally such profound nuclear changes cause cytoplasmic disturbances. The earliest visible cytoplasmic changes, as pointed out by Paillot, occur within the mitochondria. The filaments disintegrate and are replaced by dispersed granules. Later, after the nucleus has become entirely incapacitated, the entire cell disintegrates and the inclusion bodies escape into the body cavity. It is remarkable how much injury the affected nuclei withstand before disintegration occurs. The disintegration of the cells beset with polyhedra is probably independent of, although coexistent with, the lysis of all the tissues mentioned previously. Shortly after death all the tissues in the body disorganize, but it is difficult until the very last to detect any changes within the cells of the muscles, intestinal epithelium, Malpighian tubes, salivary and other glands, ganglia, nerves, gonads, etc.

The writer does not care to make any final pronouncement. However, with the evidence obtained from silkworms and tent caterpillars the safest view, in regard to the nature of the inclusion bodies, seems to be the one adopted previously (1913–16) in work on gipsy moth larvæ, namely, that the polyhedra are reaction bodies, arising in certain tissues as by-products of special nuclear changes produced by the virus.*

Normal and Pathological Blood Cells.—Since the blood has been used so much by various workers in determining whether an insect is suffering from polyhedral disease, and if so, how far the condition has progressed, a study of silkworm and tent caterpillar normal and pathological blood cell elements was undertaken. The cells were first studied in the fresh state, to observe whether pseudopodial formation with independent progression occurred, and to obtain a clear picture of the living cells. The same specimens were later fixed and stained by a variety of methods including those of Giemsa, Romanowsky, and Wright. The classification used by Paillot (11), and by Metalnikov and Gaschen (12) for insect blood cells was followed in so far as possible. Figs. 1 to 7, Plate I, represent sketches made from the dominant type of cell found (approximately 40–50 per 100 cells). Figs. 2 and 3 represent fixed and stained specimens, the others living cells. Fig. 7 shows one in the act of dividing. These cells are large elements each with a large nucleus and a considerable amount of clear cytoplasm. They show active ameboid movement and pseudopodial processes. These are the real leucocytes or phagocytes (macronucleocytes of Paillot) which engulf bacteria and foreign bodies.

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*Good photomicrographs of nuclear lesions given in earlier work. See bibliography, especially under (3). Wilt of gipsy-moth caterpillars. J. Agric. Research, 1915, iv, 101.

The next most common type numerically (approximately 25–30 per 100) is represented by Figs. 8 to 11. These cells are generally somewhat smaller than the foregoing, are rounded or oblong, and never show any ameboid movement. The nucleus is quite small in comparison to that of the phagocytes and the cytoplasm has the appearance of being denser. As shown in Figs. 10 and 11 they often contain large granules resembling the eosinophilic granules in higher animals. These cells are the proleucocytes (micronucleocytes of Paillot).

In silkworms the lymphocytes rank next numerically (approximately 10–15 per 100). These are represented in Figs. 12 and 13, and are rounded elements with each a large nucleus, and a small amount of granular cytoplasm. They never show independent movement. Fig. 14 represents the spherule or mulberry corpuscle, so called on account of its superficial resemblance to a mulberry. This type of cell is not very common in silkworms, ranking fourth numerically (approximately 10–15 per 100). In tent larvæ they are exceedingly common, ranking second in abundance (approximately 25–30 per 100). They can be readily distinguished from the other blood cells by adding a little neutral red to the preparation. This will produce a picture showing curious, irregularly rounded cells with a peripheral zone of spaces filled with red staining spherules. The same cells are often encountered with the spaces empty, Fig. 15. The nucleus is large and centrally located. On crushing the spherule cells with their vacuoles filled, one obtains a picture, Fig. 18, which shows the scattered spheres, and the nucleus distorted and elongated by crushing. The spherule cells have no independent movement. They have often been mistaken for pathological cells and the cytoplasmic spherules for polyhedra.

Fig. 16 represents a type of cell not common, but which probably ranks fifth numerically in silkworms and tent caterpillars. This is the œnocyte-like or pseudo-œnocyte corpuscle, falsely called œnocyte. It is a non-motile, large, rounded or oblong cell with a dense, homogeneous cytoplasm and a small nucleus. It has a light yellow tint in the fresh state, and superficially resembles the stationary, large, glandular cell found around the spiracles and properly called œnocyte. Lastly, at times, giant cells are encountered. These are found in the blood of perfectly normal animals and are simply huge cells containing five, six, or more nuclei. Figs. 17 and 19 represent degenerating forms of unknown cells found in normal blood. Naturally, these various types of cells vary somewhat in aspect; during metamorphosis when the phagocytes especially are loaded with metabolic products.

In diseased larvæ polyhedra develop within the nuclei of the phagocytes, proleucocytes, and lymphocytes; in those cells which are considered, by some workers, to represent stages or transitions of the same element. The inclusions are never found within the nuclei of mulberry corpuscles or œnocyte-like cells. We have never found them in giant cells. When a few small refractive bodies are found within the nucleus of a phagocyte, as shown in Fig. 20, it is rather difficult to decide whether infection has occurred or not. The writer has seen such pictures, but the larvæ subsequently failed to develop symptoms. When such nuclei are encountered as represented in Fig. 21 or 22, however, there can be no doubt that the insect will sooner or later succumb. As is the case within the other tissues, the polyhedra develop within the nuclei of the blood cells; when found in the cytoplasm, they have been phagocytized while free in the plasma. The origin of the inclusions in the blood cells is also preceded by a concentration of the nuclear substance and the formation of a central denser mass. Around this, one finds a zone in which refractive granules appear which gradually develop into polyhedra, and later completely fill the nucleus in the manner outlined for the other tissues.

During the last stages of the disease, when the tissues and blood cells begin to disorganize, myriads of polyhedra are found floating around free in the blood plasma. These free polyhedra, together with the liberated fat drops from the disintegrating fat body, give the blood of heavily diseased silkworms the appearance of milk. From the outline just given, it is evident that the blood is a fairly reliable index of the condition of a particular larva, and if two blood examinations are made on each animal, with an interval of a few days, one can be fairly certain whether polyhedral disease exists or not.

The Specificity of a Particular Virus for a Particular Host.

In 1915, the writer (1) pointed out that, although the gipsy moth reached this country in 1869 and became a serious pest in 1889, wilt among the larvæ was unknown prior to 1900. It can be safely stated that during a period of eleven years, before active suppression work was begun by the state of Massachusetts, not a single case of wilt was seen or recorded, although entomologists and field men were continually on the lookout for parasites and diseases. At that time, it was known that wilt produced epidemics among gipsy moths in the Old World and Wipfelkrankheit, a similar disease among nun moth larvæ in Europe, had been recognized before 1892 when Tubenf (13), Tangl (14), Wachtl and Kornauth (15) made valuable contributions to the subject.

When wilt appeared in this country in epidemic form after 1900, entomologists and others began to wonder how the gipsy moth, heretofore such an extraordinary healthy insect, acquired such a serious disease which proved of tremendous aid in the natural control of the pest. At that time it was recognized that a wilt occurred among some of our native American forms, especially among the apple tree tent caterpillars. The theory was advanced that tent wilt and gipsy wilt were identical, that the race of gipsy moths accidentally imported into America were immune, and that this immunity was gradually lost. Another theory assumed that the European Wipfelkrankheit and wilt were identical and that the former disease was imported into America after 1900 through the importation of trees and shrubs. A third theory assumed that all the polyhedral diseases were different, and that gipsy wilt was imported from European gipsy moths with plant shipments or with some of the insect parasites sent over here from Europe by the Federal Government after 1905.

No proof for any of these views has existed up to now, and to see whether some of these diseases, so similar superficially, were due to the same etiological agent or not, some experiments were undertaken. Three viruses were used, namely, the gipsy moth wilt virus, the tent wilt virus, and the silkworm grasserie virus.

Experiments 7 and 8, Table I, represent twenty tent larvæ fed with emulsified silkworm grasserie cadavers. In Experiments 9 and 10, the grasserie virus, which had been passed through a Berkefeld "N" candle, was inoculated into twenty tent larvæ. In Experiment 11, ten tent larvæ were fed with emulsified gipsy wilt cadavers, and in Experiment 12, ten tent larvæ were inoculated with a Berkefeld filtrate of the same virus. Although these viruses were known to be virulent for the hosts from which they were derived, not a case of wilt developed among the sixty tent larvæ.

Experiments 6 to 11, Table II, include infection experiments on silkworms (by feeding and inoculation) with the tent and gipsy moth wilt viruses. No polyhedral disease developed among any of the sixty silkworms so treated.

These experiments show, therefore, that the grasserie, tent wilt, and gipsy wilt viruses are distinct and specifically limited to their hosts.

Immunity and Transmission of the Virus Through the Egg.

Experimenters have often noticed that a certain number of infected larvæ do not develop polyhedral infection and transform into moths. In 1915, the writer observed this immunity in his experiments, and also called attention to the same fact in his field studies on gipsy moth wilt. During a severe epidemic of wilt, in a heavily infested wood lot, thousands of gipsy larvæ die daily of the disease; and the body fluids everywhere soil the leaves which are eaten by others. Congregation in immense masses on the trees also occurs prior to pupation, and in such places the mortality is tremendous. An enormous reduction in the number of adult moths, and consequently in the number of egg clusters deposited will occur, but a complete extermination is never possible owing to the immunity of certain individuals in each generation

Survival of a certain number of infected individuals again occurred during the progress of the present work. Ten tent larvæ and fifteen silkworms resisted disease after unquestionable infection. Rebouillon (16), in 1925, and Paillot (2), in 1926, reported the detection of grasserie in adult moths and Paillot can even detect infection within the eggs. If true this would constitute an extremely valuable discovery for the silk industry, because infected moths and eggs could be readily separated from the non-infected ones much after the very practical scheme devised by Pasteur for pebrine. However, we formerly repeatedly examined moths and eggs obtained from experimentally infected larvæ without finding any evidences of wilt. During field epidemics many female moths were dissected and examined for the presence of polyhedral bodies, but such examinations were invariably negative. Recently tent and silkworm moths and eggs were also subjected to examinations, but the writer could not obtain any positive evidence in this manner.

In 1925, eggs were obtained from some of the ten tent moths that survived the larval infection experiments previously outlined. Before death, or shortly after, all of the moths were microscopically examined for polyhedra or other evidences of wilt. These examinations were negative. In the spring of 1926, the tent egg clusters were removed from ice, and "broken up" to separate the eggs which are held together by some mucilagenous substance. Twenty-five eggs were then submerged for ten minutes in a mixture of equal parts of 1–1000 corrosive sublimate and 95 per cent alcohol. This was done to kill any virus that may adhere to the outside of the chorion. Experience has shown that the wilt virus is rapidly destroyed by this treatment. The eggs were then washed in sterile water and placed on sterile filter paper in sterile glass phials, one egg to a phial. The phials were corked with cotton. On hatching each larva received cherry leaves selected from a region entirely free from tent larvæ. The leaves were further thoroughly washed before being tendered. After growing, each larva was transferred to a larger sterile bottle. Every possible precaution was taken to keep wilt infection from these larvæ, such as keeping them in a unit in which wilt had never occurred, and keeping away attendants who had been in contact with wilt. In spite of these precautions three of the twenty-five larvæ independently contracted wilt and died in the 4th and 5th stages. The others completed their development. Naturally, if these had been confined together the mortality would have been much higher. From this experiment it seems likely that the disease is transmitted from generation to generation through the egg in a small proportion of individuals. We are repeating and continuing this work and hope to extend it to silkworms, for which form we have as yet no concrete evidence.

The Resistance of the Polyhedral Viruses to Physical and Chemical Agents.

In 1918 (17), the effects of various physical and chemical agents on the gipsy moth wilt virus were reported. The effects of dry and moist heat, of low temperature, sunlight, desiccation, putrefaction, glycerin, alcohol, and carbolic acid, etc., were recorded. We have only had the opportunity to verify certain aspects of this work on the grasserie and tent wilt viruses.

SUMMARY.

1. This study concerns itself primarily with two polyhedral diseases, namely, grasserie of silkworms and wilt of tent caterpillars.

2. The viruses of tent caterpillar wilt and silkworm grasserie are easily filterable through Berkefeld "V" and "N" candles. They can be passed through the "W" candles only with difficulty, and cannot be passed through the Pasteur-Chamberland "F" filters. These results may depend upon the size or formation of the filter pores; upon the flexibility or rigidity of the virus particles; upon the electrical charge, or upon some other factor.

3. Virulent filtrates are free from bacteria and polyhedral bodies and other visible agents that could be identified as etiologically important.

4. Under the dark field illumination with high magnification many minute, dancing granules can be observed in the filtrates. Similar granules are often seen free in the lymph of diseased larvæ, and within the cytoplasm and nucleus of pathological cells. These granules are interpreted as products of cellular disintegration.

5. Infection by the viruses occurs naturally through the mouth by feeding, but can also be experimentally reproduced by inoculation.

6. The period from infection to death varies from 4 to 24 days, with an average of 10 days. This variation probably depends upon the natural resistance of the host, upon the concentration of the virus, and upon temperature.

7. Detectable differences in size and shape exist between the polyhedral bodies of tent caterpillars and those of silkworms. Differences in size and shape exist within an individual host.

8. The polyhedral bodies can be freed from virus by repeated washing and centrifuging. The bodies so treated, entire or fragmented, are incapable of producing disease when injected into larvæ.

9. The polyhedra were subjected to certain microscopical, physical and chemical tests, but no evidence was obtained which could lead one to interpret these structures as living entities or as enveloping living material.

10. The polyhedra originate within the nuclei of the hypodermal, fat, tracheal matrix, and certain blood cells. The changes within the pathological cells are described and the intranuclear development of the inclusion bodies outlined.

11. The blood is a useful diagnostic index and can be used in following the progress of the disease. A detailed account of normal and pathological blood cells is given.

12. From all the evidence so far available it still seems necessary to regard the polyhedra as reaction bodies arising in certain tissues as by products of nuclear changes produced by the virus. They are of great diagnostic value.

13. Experiments are presented to show that silkworm grasserie, tent caterpillar wilt and gipsy moth wilt, so similar histopathologically are caused by distinct viruses. These viruses are absolutely specific.

14. It is shown that some larvæ are immune towards their specific virus.

15. It has so far been impossible to detect polyhedral disease within moths and eggs, but an experimental result is presented which seems to demonstrate that the tent virus is transmitted from generation to generation through the egg.

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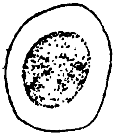
EXPLANATION OF PLATE XVII.

SKETCHES OF NORMAL AND PATHOLOGICAL SILKWORM BLOOD CELLS.

Figs. 1- 7.	Normal leucocytes or phagocytes.
Figs. 8-11.	Normal proleucocytes.
Figs. 12-13.	Normal lymphocytes.
Fig. 14.	Normal spherule or mulberry corpuscle treated with neutral red to show spherules in peripheral spaces.
Fig. 15.	Normal spherule cell with peripheral spaces empty.
Fig. 18.	Normal spherule cell crushed, showing discharged spherules, and elongated nucleus deformed by crushing.
Fig. 16.	Normal œnocyte-like cell.
Figs. 17 and 19.	Degenerating forms found in normal blood.
Fig. 20.	Leucocyte, at times found in grasserie infected larvæ with a few questionable inclusions within nucleus.
Fig. 21.	Pathological leucocyte found in grasserie larvæ showing many small polyhedra within nucleus.
Fig. 22.	Pathological leucocyte in grasserie larvæ showing entire nucleus filled with fully developed polyhedra.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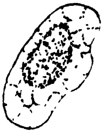
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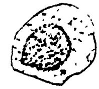
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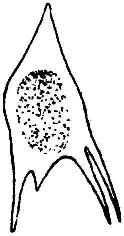
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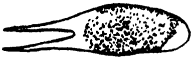
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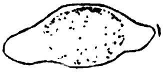
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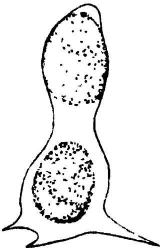
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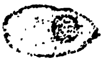
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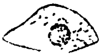
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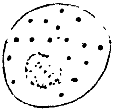
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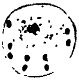
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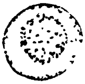
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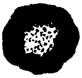
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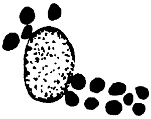
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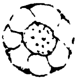
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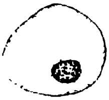
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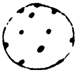
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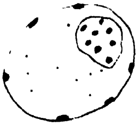
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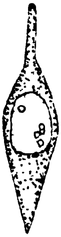
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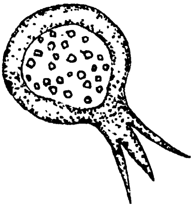
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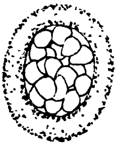
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R. W. Glaser.

NOTES ON A FEW APHID SPECIES AND THE GENUS ILLINOIA WILSON.

By C. P. GILLETTE,
Colorado Agricultural Experiment Station.

Aphis oenotheræ Oestlund

In his "Synopsis of the Aphididæ of Minnesota," Bul. 4 of the "Geological and Natural History Survey of Minnesota," 1887, p. 62, Dr. Oestlund describes a light green aphis occurring upon *Oenothera biennis*, giving it the name *oenotheræ.* The entomologists of the country seem quite generally to have attached this name to a similar, but quite distinct, species common in the eastern states, which seems to have escaped description and which apparently confines its attacks to *Oenothera biennis.* A large number of records on these two species indicate that the one so well described by Dr. Oestlund is extremely common on *Oenothera* and *Epilobium* species in Colorado, while the undescribed species is rarely taken in this state.

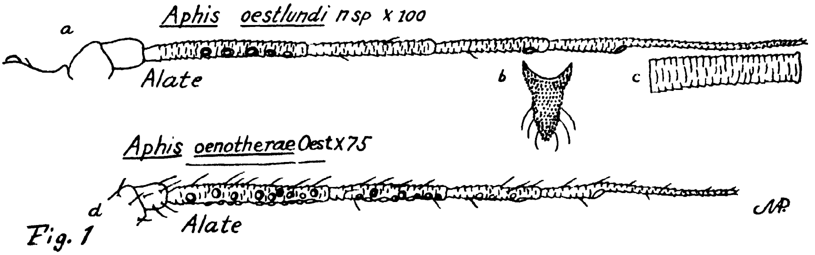
Oestlund's *oenotheræ* also resembles very closely, in structure, examples of *A. epilobii* Kalt. from western Germany, loaned to me for study from the United States National Museum by Dr. P. W. Mason. The European examples, though rather close to *oenotheræ*, were mutilated and not in a favorable condition for study. It does not seem at all probable that this European species that has not been reported, so far as I am aware, east of the Mississippi River in this country and is known to occur only on *Oenothera biennis*, is the same as that described by Dr. Oestlund, which is so abundant in the western United States and in northern Colorado, at least, to an altitude of 9000 feet or more in the Rocky Mountains.

Dr. Oestlund, in his "Synoptical Key to the Aphididæ of Minnesota," in the "19th Report of the State Entomologist of Minnesota," Sec. B, 50; 1922, p. 130, indicated the undescribed species instead of the one originally described by him as *oenotheræ.* The undescribed species may be characterized as follows:

Aphis oestlundi, n. sp.

Alate Viviparous Female: Head, thorax, antennæ, cornicles, tarsi, distal ends of tibiæ and femora, black or blackish; cauda of same color as the abdomen. Length to tip of cauda, 1.10 to 1.70 mm.; antenna, .80 to 1.00 mm.; 4 to 6 large sensoria in a row on joint 3, none on joints 4 or 5; length of joints about as follows: III, .22; IV, .17; V, .15; VI, .10; spur, .25 mm.; cornicles, .20 mm.; cauda a little longer than tarsus; wings transparent, venation normal. See Fig. 1, a, b, and c, by Miss Palmer.

Apterous Viviparous Female: General color, light green; cornicles and cauda much paler; tips of antennæ, tarsi, distal ends of tibiæ, and extreme tips of cornicles dusky to blackish. Length of body, 1.80 to 2 mm.; cornicles, .20 to .30 mm., cylindrical or slightly tapering with weak flange.



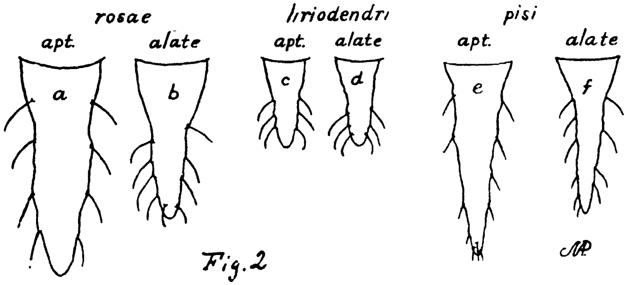


Fig. 1. a, antenna; b, cauda; c, cornicle of *Aphis oestlundi*, n. sp.; d, antenna of *Aphis oenotheræ*.

Fig. 2. Caudas of apterous and alate forms of *Macrosiphum rosæ*, *M. liriodendri* and *M. pisi*.

Described from examples taken on *Oenothera biennis* as follows:

Orono, Me., June 27, 1924; E. M. Patch collector. Types.
Monmouth Junction, N. J., May 30.
College Station, Texas, May 19, 1916; F. B. Paddock collector.
Rocky Ford, Colo., May 28, 1907, L. C. Bragg, collector.
Fort Collins, Colo., June 12, 1907; L. C. Bragg collector.
Boulder, Colo., June 14, 1910; C. P. Gillette collector.
Minneapolis, Minn., June 11, Oestlund; 9828 National Museum collection.
War Bonnet Canyon, Neb., June 24, 1890; T. A. Williams; two slides, Nos. 97 W and 99 W, in National Museum collection.

It is interesting to note that all the records for this species are in May and June, indicating that there may be an alternate midsummer host.

Aphis oenotheræ Oest., is a very common and extremely abundant species in northern Colorado, extending far up in the foothills and continuing until killed by heavy freezes in late fall.

Aphis oenotheræ Oest., var. **rufa,** n. var.

On August 29, 1926, at an altitude of about 10,000 feet on Cameron Pass, Larimer County, Colo., where *Aphis oenotheræ* was extremely common on *Epilobium*, one plant was taken, heavily infested with a pale, rusty-yellow *Aphis* clustered in the flower head. The color was so very different from the dark slaty color of *A. oenotheræ*, that I took it to be a very distinct species. However, upon mounting these lice in balsam for microscopic examination, they became exactly like *oenotheræ* in appearance, and I have been unable in any way to separate them from that species. They may be described as follows:

Alate Viviparous Female: Color of abdomen pale rusty-yellow; head, thorax, tarsi distal ends of tibiæ, femora and antennæ black. Cornicles and cauda colored like the abdomen, but somewhat darker, especially in the older individuals.

Measurements: Length of body,* 1.80 to 2.12 mm.; antennæ, 1.10 to 1.12 mm.; cornicles, .25 mm.; cauda, .15 mm.; joints of antenna, III, .30; IV, .23; V, .18; VI, .12; spur, .25 mm. Sensoria: Joint III, 18 to 26; IV, 8 to 16; V, 3 to 10; VI, 0 to 1. See Figure 1, d by Miss Palmer.

Apterous Viviparous Female: Color of entire body pale rusty-yellow; antennæ paler than the body; cauda a little darker than the body; antennæ dusky in distal half; legs light yellow, with tips of tibiæ and tarsi black. Body very slightly dusted with a fine powder which is hardly discernible in many of the individuals.

Measurements: Length of body, 2 mm.; antennæ, .10 mm.; joints of antennæ; III, .28 to .32; IV, .18 to .22; V, .15 to 17; VI, .10 to .11; spur, .18 to .20 mm.; cornicles, .37 mm. The cauda equals tarsi in length, constricted little or not at all in the middle.

Nymphs tesselated, in general color, like the larvæ.

Aphis helianthi Monell.

There is danger that entomologists may confuse *Aphis helianthi* Monell with the aphid described as this species by Oestlund in his "Aphididæ of Minnesota," 1887, p. 52, and again referred to as the same species in his "Synoptical Key to the Aphididæ of Minnesota," p. 129, in the "Nineteenth Report of the State Entomologist of Minnesota," 1922. This species now belongs in the genus *Anuraphis* Del Guercio. The alate summer form has sensoria on joints 3–5 of the antenna, which are strongly tuberculated on joints 3 and 4; the cornicles and short triangular cauda are about equal in length, and the leaves upon which the louse feeds are corrugated. The species seems to be *middletonii* Thomas.

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*All body measurements include the cauda.

In the case of *helianthi* Monell, the sensoria are confined to joint III; they are almost flush with the surface so that the joint appears smooth; the cornicles are nearly as long as the third joint of the antenna; the cauda is of the normal *Aphis* type, conical and upturned, and the louse does not cause any distortion of the leaves upon which it feeds. It is the common plant louse occurring on the under side of the leaves of both native and cultivated sunflowers in this country.

Genus **Illinoia** Wilson

Professor H. F. Wilson, in his "Key to the Genera of the Subfamily Aphididæ and Notes on Synonomy," published in "Annals of the Entomological Society of America," December, 1910, p. 318, erected the genus *Illinoia,* and set *Siphonophora liriodendri* Monell, as the type.

The diagnostic characters in Wilson's description of this genus seem to be: Antennæ on prominent tubercles, first segment strongly gibbous; tubercles not gibbous; cauda constricted near the middle, and very long cornicles constricted and reticulated near their tips.

Mr. A. C. Baker in his "General Classification of the Hemipterous Family Aphididæ," Bulletin 826, United States Department of Agriculture, p. 56, gives as the characteristics of this genus: "Prominent, diverging frontal tubercles * * *; subcircular sensoria * * *; cornicles cylindrical, * * *, cauda conical and, not as in *Macrosiphum,* with a constriction near its base" (Just the opposite of Wilson's description of the cauda but correct for most examples of *liriodendri* that I have examined). See Fig. 2, c and d. The caudas of the adult lice are quite variable and may be slightly constricted near the middle, and are rather short for *Macrosiphum.*

The illustration of the cauda of *liriodendri* in Baker's Plate 8, Fig. J, in the paper above mentioned, does not apply well to the adult form in the examples I have studied, including Monell's types. The cauda usually has a length that is nearly if not quite twice its breadth at the base. I also have examples of this species from Mr. J. J. Davis, which he took at Urbana, Illinois, and examples taken by Mr. F. H. Chittenden and by myself in Washington, D. C., and can see no sufficient reason why any of these should not be included in the genus *Macrosiphum* as they agree in every detail with the characterization of this genus as given by Mr. Baker in his "Generic Classification," above mentioned on p. 57, except that the cauda is rarely constricted in the middle, which is sometimes true also of *rosæ*, the type of the genus. If *liriodendri* is to form a new genus, it should be on account of the unusually long spur to joint VI of the antennæ, the moderately gibbous second joint, which is not uncommon in *Macrosiphum*, and the rather short cauda and frontal tubercles; but these characters are comparative and not sufficient to warrant the erection of a new genus in the opinion of the writer. Theobald, in a footnote on p. 35 of his "Plant Lice or Aphididæ of Great Britain," 1926, says: "The difference between *Illinoia* and *Macrosiphum* is very slight, being based only on the comparative length of the cauda. Typical *Illinoia* have it distinctly conical, but from that form to the long cauda in *Macrosiphum* there are many intermediate species." See Fig. 2, a, b, c and d by Miss Palmer.

Macrosiphum pisi Kalt.

Even if *Illinoia* should be retained as a new genus, there seems to be no good reason for including *Macrosiphum pisi* in it, as has been done by several recent writers. This species agrees in every detail with Baker's characterization of *Macrosiphum*, except that the cauda (Fig. 2, e and f) is rarely constricted at the middle, but it does closely resemble the cauda of *M rosæ.* Its structural characters in general are more like *rosæ* than *liriodendri.* In the opinion of the writer, both *pisi* and *liriodendri* should be placed with *rosæ* in the genus *Macrosiphum.* Typical caudas of *rosæ*, *liriodendri* and *pisi* are shown in Fig. 2.

SOME UNDESCRIBED DIASPINES FROM MISSISSIPPI.*
(Homoptera: Coccidae)

By GLADYS HOKE,
A. and M. College, Mississippi.

Descriptions of four species are presented for publication in anticipation of the use of the names in a forthcoming technical bulletin on the Diaspines of the state to be published by the Mississippi Experiment Station.

Aspidiotus socialis, new species.

Scale of Female.— Color yellowish brown;moderately convex, circular; exuvia sub-central, covered by secretion; 1 mm. in diameter.

Scale of Male.—Not observed.

Adult Female.—Body longer than broad, in older specimens pygidium telescoped into preceding abdominal segments until as broad as long; rudimentary antennæ bearing a stout seta; spiracerores lacking.

Pygidium.—Lobes in three pairs, median pair large, prominent, mesal margins parallel and fused for more than half their length, distal margin rounding into lateral, slight indication of lateral notch near base; second pair of lobes short, reaching only slightly beyond base of median lobe, narrow, converging toward median lobes, chitinized, lateral notch; third pair of lobes much reduced, converging toward meson, chitinized, slight lateral notch or crenulation; incisuræ very narrow; thickenings along edges of incisuræ (densaræ) conspicuous, mesal thickening of second incisura club-shaped, long and broad, lateral thickening smaller, those of third incisura shorter, sometimes apparently fused at cephalic end, thickenings of median incisura sometimes inconspicuous, a small thickening on lateral basal portion of a median lobe usually conspicuous; plates observed only in third incisura, long as setæ and slender, not discernible in some specimens; a dorsal seta at base of lateral margin of each lobe, one on lateris and one at base of pygidium; a ventral seta in close proximity to each dorsal seta; genacerores lacking; a ceratuba opening in groove between median lobes, three in grove from second incisura, a row of about six from third incisura, and about the same number in a row extending cephalad from near seta on lateris; anus small, about four or five times its width from distal end of lobes; vulva located in line with the setæ located on lateral margin of pygidium at its base; viviparous.

Host.—Bark of water-oak (*Quercus* sp.).

Locality.—Aberdeen, Mississippi: May 4, 1921. Collected by Dr. H. L. Dozier. Well developed embryonic larvæ were observed in one specimen. The absence of genacerores is apparently the chief morphological difference between this species and *A. forbesi.* Dr. Harold Morrison suggests that it is also probably closely related to *A. ehretiæ* (Brain). *Chrysomphalus obscurus* (Comst.) occurred in great numbers associated with this species. *Aspidiotus coloratus* Ckll. and a species of *Kermes* were collected from the same tree. On August 18, 1921 Argentine ants were collected "attending coccids" on the tree from which these species were taken.

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*Contribution from the Mississippi Agricultural Experiment Station.

Holotype in the Coccid Collection of the Mississippi State Plant Board. Paratypes in the U. S. National collection of Coccidæ, Washington, D. C. and in the author's collection.

Crypthemichionaspis ulmi, new species.

Scale of female.—Color white when clean, if weathered, a dirty white, or if secretion has been removed exuviæ showing as shiny black, specimens examined .8 to .9 mm. long, .4 mm. broad, pygidial portion much narrower, very convex, about .2 mm. high; ventral scale white, adhering to insect except beneath abdomen where it apparently usually adheres to bark, first exuvia at anterior end, delicate, covered by secretion, pale straw yellow when removed, black of second exuvia showing through when in place; position of first exuvia indicated on second which is shiny black and heavily chitinized, portions of pygidium and ventral surface less heavily chitinized than cephalothorax; plates visible on margin of pygidium.

Scale of male.—Color white; .8 mm. long, .3 mm. broad, sides parallel, concentrically ringed, exuvia terminal covered with white secretion, pale straw color; posterior end of scale open to allow for exit of male.

Adult male.—Body .56 mm. long; with wings folded back .75 mm. long not including antennæ, .16 mm. broad; legs with a button-like structure between tibia and tarsus.

Exuvia of male.—Apparently not differing from that of female.

First exuvia of female.—Mounted on slide apparently .39 mm. long, .26 mm. broad; antennæ 6–segmented; distal segment with 6 or 7 setæ; tarsus twice as long as tibia; each abdominal segment apparently with a ceratuba opening on slight prominence on margin, slight median notch on margin of pygidium; 2 slender setæ folded back and crossed on pygidium; a pair of very short median lobe-like projections of margin, 2 setæ associated with each; slight indication of a second pair of lobes; and beyond each of these a large and long plate; several setæ on lateris; rostrum folded back in close proximity to margin.

Second stage female.—Body apparently .46 mm. long; .29 mm. broad; rudimentary antennæ with 3 stiff setæ; segmentation distinct; margins of abdominal segments bearing 2 or more short tubercles or stiff plates; pygidium with lobes in 2 pairs, median pair broad, deeply incised forming 2 lobelets, median largest, distal end with 2 deep notches giving a trilobed appearance, lateral lobelet without notches; second pair of lobes similar to first pair but very much smaller, sometimes apparently wanting; median pair of lobes widely separated; 8 pairs of long plates, 2 pairs of large short ceratuba on margin, first between second plate and median lobe, second ceratubæ between third and fourth plates; ceratubæ on ventral surface slender; anus from 5 to 8 times its own width from posterior margin.

Second exuvia.—Densely chitinized excepting last 3 abdominal segments and pygidium, these chitinized but not so heavily as anterior portion; pygidium with lobes apparently in 2 pairs, median pair large, apparently incised forming 2 lobelets, the median with 2 notches on distal end giving a trilobed appearance, lateral lobelet much smaller and without notches; second pair of lobes incised, but very small and inconspicuous; 7 or 8 pairs of plates, long, stout, and chitinized, apparently arranged 2–1–1–1–1–2; 2 pairs of short stout ceratubæ opening on margin mesad of fourth and of second plates; a seta at base of each of lobes and 2 on lateris, possibly more; anus about 3 to 4 times its own length from margin.

Adult female.—Body mounted on slide .44 to .59 mm. long, .39 mm. broad, some specimens with one side much straighter than other; derm membraneous; rudimentary antenna bearing 3 or 4 long stout setæ and 2 or 3 shorter, slenderer ones; tentorium large and chitinized; anterior spiracles with 2 or 3 spiracerores; posterior spiracerores lacking; 2 small setæ caudad and mesad of anterior spiracle; a few small scattered setæ.

Pygidium.—Lobes lacking; margin unbroken; apparently 4 pairs of long setæ on margin, median pair ventrad of others; and 6 or 7 smaller submarginal setæ on ventral surface; ceratubæ submarginal, slender, each side apparently with 4 groups of about 3 or 4 each except last of only 1 or 2; genacerores in 3 groups, anterior groups fused forming one continuous band, posterior groups only slightly separated from median group of about 21–24 cerores, posterior groups of 4–6; 3 pairs of small setæ cephalad of genacerores, and three pairs on each of two preceeding segments, 2 pairs on third, and 1 to 2 on second abdominal segment, dorsal surface bearing 7 pairs beginning with first abdominal segment one pair on each segment, and 2 on pygidium; anus superimposed on vulva, about 3 times its own width from margin.

Host.—Elm (*Ulmus americana L.*).

Locality.—Freshman baseball field, A. & M. College, Mississippi: October 15, 1926. Collected by Mr. J. N. Roney.

This species was most abundant in cracks of the bark or partly or completely beneath the scales of *Aspidiotus juglans-regiæ* Comst. The scales of the latter species were often partly elevated from the bark and 2 or more specimens of the *Crypthemichionaspis* were often found beneath one old scale, and also beneath females of *Lecanium caryæ* Fitch. The *Aspidiotus* and the *Lecanium* were heavily parasitized though no evidence of parasitism was observed in the *Crypthemichionaspis*. At the suggestion of Dr. Harold Morrison of the U. S. Bureau of Entomology, Washington, D. C., this species has been placed in the genus *Crypthemichionaspis* of Lindinger. It appears to be closely related to *Crythemichionaspis africana* (Newst.).

Holotype in the Coccid Collection of the Mississippi State Plant Board. Paratypes in the U. S. National Collection of Coccidæ and in the author's collection.

Lepidosaphes ilicis, new species.

Scale of female.—1.48 mm. long, very slender, little broader than exuviæ, transparent, body of insect showing through very distinctly, scale appearing on leaf as nearly white; exuviæ occupying one-half of total length of scale, first exuvia projecting entirely beyond scale, overlapping second only slightly, covered with thin white secretion, faint glistening straw-yellow color with secretion removed; ventral scale very delicate, not noticeable on leaf and only apparent as fringe along lateral margins beneath dorsal scale.

Scale of male.—Slightly shorter than scale of female, slightly opaque, otherwise very similar and scarcely distinguishable from female scale except by presence of only one exuvia in male scale.

Embryonic larva.—Body about .23 mm. long, .13 mm. broad; 2 chitinized tubular ducts near cephalic margin of head; antenna apparently 5 segmented, distal segment annulate; coxa and femur of each leg very broad; pygidium with a pair of large lobes, a pair of small lobe-like processes between large pair; ventral surface with a long seta and a short one between large and small lobes and apparently with 2 setæ on dorsal surface about opposite these.

Adult male.—Body, mounted on slide, 1 mm. long from base of antennæ to end of genital sheath, and twice as broad from tip of wings with these expanded, antennæ and legs apparently of usual type, basal portion of halter rather slender at base and broadly expanded toward apex, bristle slender, hook with slightly more than a right angle, basal portion of wing with distinct protrusion with pocket for hook.

Second stage female.—Derm membranous except portions of pygidium; antennæ rudimentary, bearing a long seta, apparently one anterior spiracerore; tentorium well developed; margin of body bearing small setæ, margins of abdomen and thorax with ceratubæ; pygidium with lobes in three pairs, median pair well developed, as broad as long, distal half broadly rounded with indication of a notch near lateral margin, second pair of lobes deeply incised, mesal lobelet similar to median lobe but smaller, lateral lobelet much reduced and bluntly pointed at apex; third pair of lobes scarcely recognizable as such, deeply incised, lateral margins serrate; median incisura almost as broad as a median lobe, second and third about same width; plates arranged 1–1–1; a dorsal and a ventral seta at base of each lobe, on lateris, and near base of pygidium, apparently with an extra dorsal seta at base of median lobe; 5 pairs of broad altaceratubæ, arranged 0–1–1–1–1–1, with 2 or 3 pairs of small slender ceratubæ on dorsal surface laterad and cephalad of anus but nearer margin; anus about 8 times its own width from distal end of lobes; 2 pairs of chitinized thickenings on ventral surface extending cephalad from base of median and of second pairs of lobes, median pair converging and almost meeting at a point slightly cephalad of anus; second pair beginning short distance cephalad of second pair of lobes.

Adult female.—Body mounted on slide 1 mm. long, .24 mm. broad, cephalic end very bluntly rounded, pygidium bluntly pointed; derm membranous except portions of pygidium; antenna very rudimentary, each bearing 1 long and 1 short seta, a portion of derm between antennæ apparently protruding slightly and lacking finger-print-like markings of adjacent derm; tentorium long not heavily chitinized; derm adjacent to anterior portion of rostrum bearing numerous small chitinized, papilla-like projections; anterior spiracerores 3–6; thorax longer than abdomen and pygidium.

Pygidium.—Lobes in 3 pairs, median pair large, as broad as long, deeply rounded, serrate almost to base; second pair deeply incised, median much larger than lateral lobelet, serrate on lateral margin, lateral lobelet small, pointed, often without serrations, inconspicuous; third pair similar to second, broader and less lobe–like in appearance; incisuræ rather narrow; plates short, not longer than seta, arranged 1–1–1, median plate shorter than lobes, second as long as second lobe, third longest, as long as dorsal seta of second lobe; a dorsal and a ventral seta associated with each lobe, 2 on lateris; genacerores lacking; altaceratubæ large, arranged 0–1–2–2–2–1, paired arrangement of last two groups scarcely discernible; brevaceratubæ apparently lacking, 2 pairs of small ventral submarginal ceratubæ present on lateris; anus about 12 times its own width from distal end of lobes; vulva caudad of anus; ventral chitinized thickenings extending cephalad from median lobes for about two-thirds of distance to vulva, thickenings from second pair of lobes extending cephalad of vulva; viviparous.

Host.—Holly, (*Ilex opaca* Ait.), under side of leaves.

Locality.—Horse Shoe Lake, Tallahatchie River bottom near Como, Mississippi: October 29, 1921. Collected by the author.

The drawing of the second stage female is of a specimen on holly leaf, (*Ilex opaca*) from Flint Creek Swamp, Wiggins, Mississippi: December, 1920. Described from 2 adult females, 2 second stage females, 1 male, and the scales.

Holotype in the author's collection.

Paratype in the Coccid Collection of the State Plant Board.

Lepidosaphes solidaginis, new species.

Scale of female.—Variable; color yellowish white; usually about 2 mm. long, and three-fourth as broad, convex; first exuvia small, long, and narrow, second exuvia much larger, broad, projecting well beyond margin of scale, both exuviæ covered with secretion, scale without exuviæ often as broad as long, ventral scale white, thick, adhering to bark of host.

Scale of male.—Color similar to that of female, usually about 1 mm. long and narrow, sides of scale almost parallel, concentrically ringed, convex, exuvia about one-fourth as long as scale.

Larva.—Body about twice as long as broad, (antenna broken on specimens studied) a pair of tubular ducts on dorsal surface of head as in figure; 3 pairs of large setæ on dorsal cephalic margin, branched; legs well developed, tibia one-half as long as tarsus, coxa broad; pygidial margin with a pair of large lobes distinctly notched on inner and outer margins near base, between large lobes a pair of small chitinized lobe-like processes, deeply notched on distal end near inner and outer margins; a seta about one-third of length of body mesad of each large lobe, 2 small setæ between small median lobe-like process and large lobe, laterad and dorsad of each large lobe a short seta on a serrate chitinized projection of margin, laterad of this seta a large plate followed by a chitinized projection of margin, then a seta followed by a plate, 3 pairs of smaller plates, setæ and ceratubæ on margin as in figure; anus in close proximity to margin.

First exuvia.—Four or five pairs of setæ on anterior margin of head between the eyes, the 3 median pairs apparently may or may not be distinctly branched on distal half; antennæ 6-segmented; a pair of cylindrical ducts opening on dorsal surface of head near anterior margin; eyes marginal; a distinct constriction between anterior and posterior half of specimen; pygidial margin as in figure, the 2 long setæ folded cephlo-laterad and crossed on dorsal surface; rostrum, tentorium and legs pushed well back on to pygidium.

Second stage female.—Body slightly less than twice as long as broad, broadest through abdominal segments; rudimentary antenna bearing 2 or 3 setæ, setæ and certubæ on ventral surface of head as in figure; mesospiracerores 3-4, metaspiracerores not observed; a row of about 5 ceratubæ extending laterad from the posterior spiracles to margin, ceratubæ, and conical tubercles bearing certaubæ, extending cephalad along margin to anterior spiracles; pygidial margin with 2 pairs of short broad lobes, second pair incised; 2 plates in median incisura, 1 in second, and 1 in third; lateris chitinized and deeply serrate; a dorsal seta on inner and outer margin at base of median lobe, at base of second pair of lobes and 2 on lateris, a ventral seta cephalad of first 2 dorsal setæ and laterad of remaining three; 5 pairs of short stout altaceratubæ, a few brevaceratubæ as in figure; anus 5 to 8 times it's own width from distal end of lobes.

Second exuvia.—Pygidial margin similar to that of second stage; rostrum usually folded back to or beyond anus.

Adult female.—Body usually twice as long as broad, rudimentary antennæ bearing 2–4 setæ; groups of ceratubæ on lateral aspects of abdominal segments and on thorax as in figure; a chitinized structure on margin of head laterad of anterior end of tentorium; mesospiracerores 14–18, metaspiracerores 4–9.

Pygidium.—Lobes in 2 pairs, median pair twice as broad as long, slightly notched on inner and outer margin, second pair of lobes deeply incised, mesal lobelet more than twice as broad as lateral, lateris deeply incised and margin chitinized; median incisura as wide or wider than a median lobe, second incisura wide; plates arranged 2–1–1, median pair longest, three times as long as median lobes, converging toward apex, second and third plates sometimes unipectinate on lateral margins; a pair of setæ on ventral surface mesad and cephalad of median pair of lobes, a dorsal and a ventral seta associated with each pair of lobes, other setæ observed, as in figure; genacerores 5–7, 8–12, 7–10 in specimens observed; altaceratubæ 1–2–2–2 short and broad, brevaceratubæ large, about 12 pairs, usually as in figure; ceratubæ of ventral surface numerous, small, apparently usually with a group of about 4 cephalad of second pair of lobes, two groups of about 10 or 11 each on lateris, and a group of about 7–11 each on two preceding abdominal segments; a group of 2 about midway between vulva and posterior margin, a group of 2 or 3 between vulva and posterior group of genacerores, and 1 laterad of anterior group of genacerores; anus about 10 times its own width from distal end of lobes; vulva located between posterior groups of genacerores.

Host.—Golden rod, (*Solidago* sp.) Scales clustered at the base of the main stem in close proximity to the roots and on the roots near the stem.

Locality.—Pickens County, Alabama, September 8, 1925. Collected by Mr. George F. Arnold. The specimens were collected so near the Mississippi state line that it seems logical to include the species in this paper. A number of these scales had been parasitized but none of the parasites were collected.

The most outstanding morphological characteristics of this species seem to be the exceedingly long plates of the median incisura, the presence of only one plate in the second and in the third incisura, the chitinized and dentate lateris, the large number of anterior and posterior spiracerores, and the presence of grouped ceratubæ on the ventral surface.

Holotype in the Coccid Collection of the Mississippi State Plant Board. Paratype in the author's collection and specimens from the type material in the U. S. National Collection of Coccidæ at Washington.

EXPLANATION OF PLATES.

(The drawings were made by Mrs. G. G. DeBord, DeBord Laboratories, Fort Smith, Arkansas).

PLATE XVIII.

Aspidiotus socialis, new species.

Fig. 1. Adult female, × 51.
Fig. 2. Pygidium, × 193.

Crypthemichionaspis ulmi, new species.

Fig. 3. First exuvia, × 129.
Fig. 4. Second exuvia, dorsal, × 58.
Fig. 5. Adult female, ventral, × 87.
Fig. 6. Male, portion of hind leg, × 331.
Fig. 7. Second exuvia, pygidium, × 193.
Fig. 8. Adult female, pygidium, × 267.

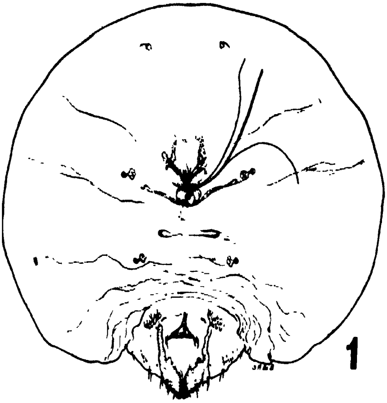
PLATE XIX.

Lepidosaphes ilicis, new species.

Fig. 9. Adult female, × 79.
Fig. 10. Male, halter, × 500.
Fig. 11. Female, second stage, pygidium, × 331.
Fig. 12. Adult female, pygidium, × 267.

Lepidosaphes solidaginis, new species.

Fig. 13. Larva, × 129.
Fig. 14. First exuvia, × 129.
Fig. 15. Second exuvia, pygidium, × 127.
Fig. 16. Second stage female, × 79.
Fig. 17. Adult female, genacerore, × 733.
Fig. 18. Adult female, pygidium, ×141.
Fig. 19. Adult female, ventral, × 51.



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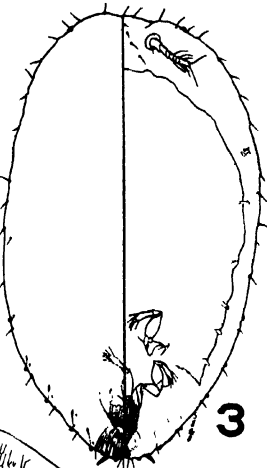

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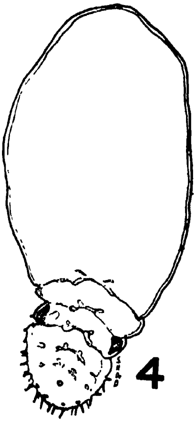

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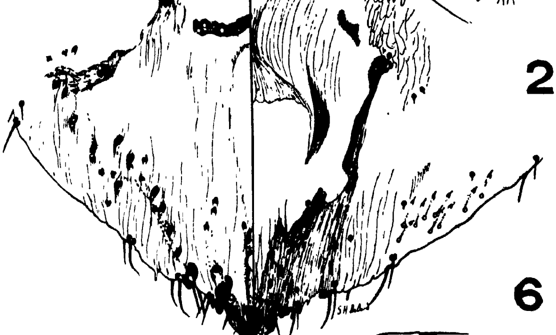

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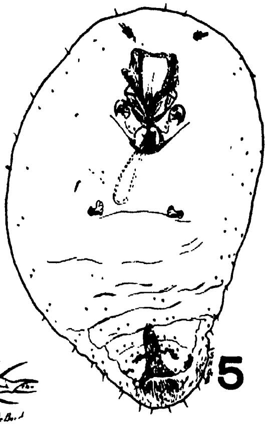

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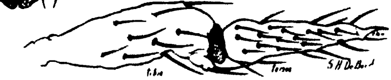

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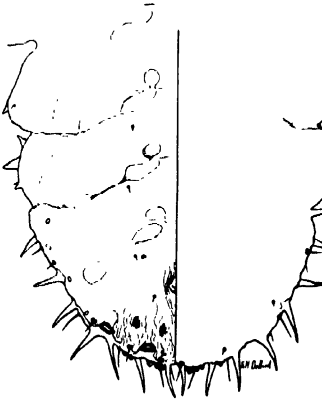

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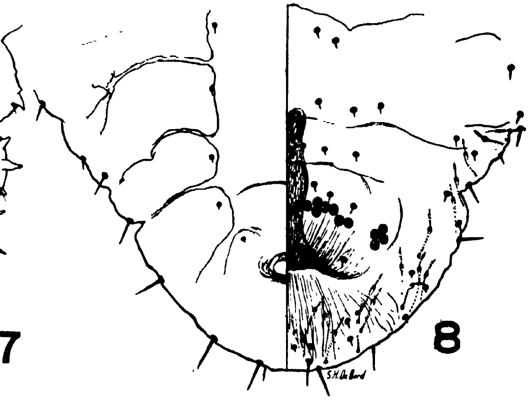

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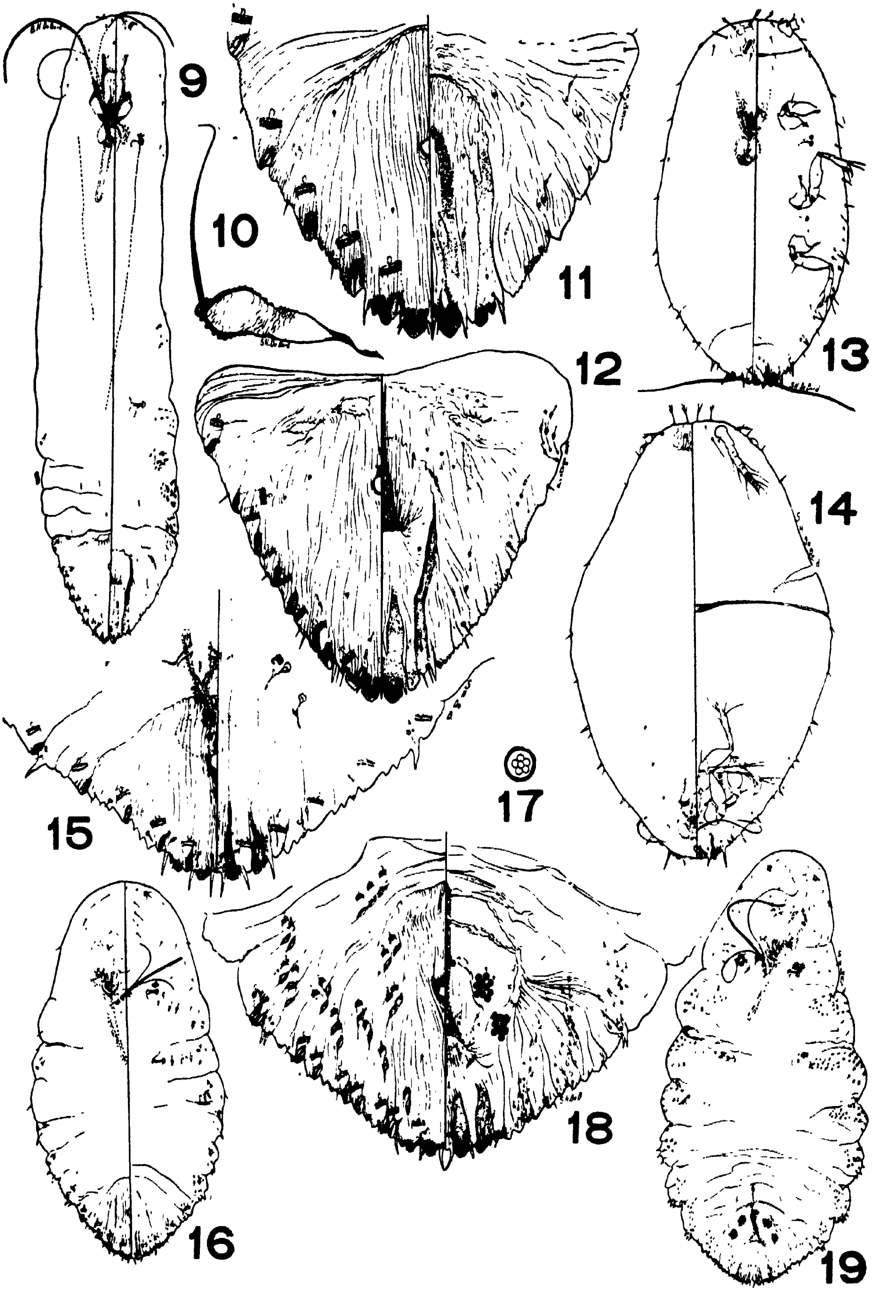
Gladys Hoke



Gladys Hoke

CILIATED EPITHELIUM IN THE INSECTA.

By A. C. Davis,
University of California.

The absence of ciliated epithelium in the Arthropoda has, until recently, been considered as one of the principal characters of the phylum. This rule may hold true in the majority of cases, but I believe it will by no means hold true in all.

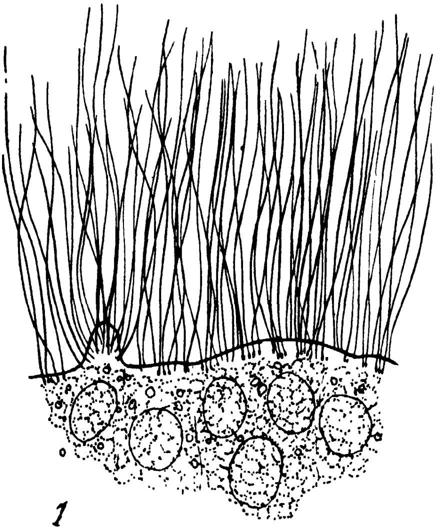
In the Insecta there seems to be some debate as to whether or not ciliated epithelium exists. The best known example is the epithelium of the Malpighian tubules, the cells of which are covered, on the side toward the lumen, by a thin hem or layer of what appear to be short, non-vibratile cilia. Berlese (1909, p. 786, Figs. 973 and 974) figures these cells, and plainly labels the apical portion "regione cigliare prossimale". Other authorities, as pointed out by Cameron (1912) have used various terms to denote this region, such as "ciliated border," "striated plate," "ciliated plate," or "plate composed of free filaments or rods," all of which convey the same idea. Other authorities have denied the existence of cilia, or have not committed themselves. In some recent work on the anatomy of *Stenopelmatus fuscus* Hald., I encountered this peculiar condition in the epithelium of the Malpighian tubules, and was at first puzzled to know what to call it. The cilia are extremely short and fine, and the basal bodies are not clear. Some workers have argued that since the tubules are of ectodermal origin, this lining of the lumen is a chitinous tube, pierced by minute pore-canals. I cannot quite reconcile this explanation with the appearance of the structure in *Stenopelmatus*, in which the ciliated hem is clearly seen in both living tubules and sections, and, to all appearances, is composed of short, non-vibratile cilia.

On the whole, I believe that insect anatomists are justified in considering the epithelium of the Malpighian tubules as ciliated until it is definitely proven otherwise. Tietz (1923, p. 263 and Fig. 23b) seems inclined to regard the lamina or striated hem of the mid-intestinal epithelium as ciliated, but queries the statement, as most writers have done. This, of course, is the safer thing to do, but, since no one seems able to differentiate certainly between these filamentous, non-vibratile processes and true cilia, it seems to me that it would be easier and less confusing to plainly call them cilia of the mid-gut epithelium.

Arguing from general invertebrate structure that cilia, if present anywhere, would be most highly developed in the reproductive tubes, I proceeded to make preparations of the living oviduct of *Stenopelmatus.* Under the high power or oil immersion of the compound microscope the epithelium of the oviduct is seen to be columnar, the walls very indistinct and the cells grouped into loose bundles. Each bundle protrudes into the lumen somewhat, giving the inner surface a warty appearance. The fact that the cells are very hard to see through, and contain globules of an opaque yellow, oily substance makes detailed study of the living cells impossible. At frequent intervals there are papillæ protruding into the lumen for about 25 or 30 microns. The whole inner surface is thickly set with what appear to be non-vibratile cilia of from 50 to 70 microns in length. By pressing the cover-glass the cilia can be made to sway back and forth in the currents. There is an incomplete row of small dark bodies just within the apical cell-wall that very closely resemble the basal bodies of cilia.

Portions of the oviduct were fixed in Bouin's and Flemming's solutions, sectioned at 8 microns, and stained with Heidenhain's iron-alum haematoxylin and eosin. In these sections the cilia are tangled and matted somewhat, but still clearly demonstrable. The cell structure is difficult to make out, but the cells are apparently very loosely packed together. The "basal bodies" can sometimes be made out, but are less distinct than in the living material. No connection can be demonstrated between the cilia and the basal bodies.

These observations, and the questionable value of cilia in the oviduct of an insect laying such large eggs as *Stenopelmatus*, made further observation necessary. Upon more careful examination it was seen that the cilia, instead of terminating at or just within the apical walls of the epithelial cells, penetrated between them, (in most cases appeared to actually pass through them) and terminated in a large, elongate, deeply staining body near or in contact with the basement membrane. Upon comparison with living spermatozoa and with spermatozoa in sections of the testis of the same species, the supposed cilia in the oviduct were seen to be without doubt the tail-pieces of spermatozoa, occurring in such great numbers as to resemble a fringe of cilia, and obscuring the details of the epithelial cell structure. In order partially to check this conclusion, an immature female *Stenopelmatus* of large size was dissected and examined. No cilia were found in the oviducts, the inner surface being quite plain.



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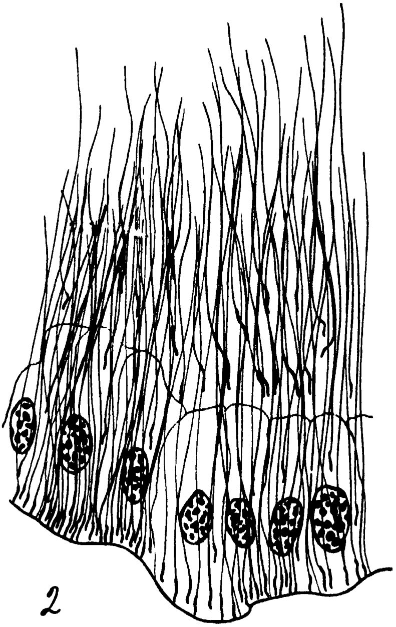

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Fig. 1. Portion of the apical part of the live oviduct epithelium, showing the sperm-tails and the false basal bodies.
Outline from camera lucida. Semi-diagramatic. × 465.

Fig. 2. Cells of the oviduct epithelium, showing spermatozoa penetrating to the basement membrane. The cytoplasm of the cells is not shown.
Outline from camera lucida. × 500.

The male of this insect has no penial organ capable of being inserted into the body of the female, and the semen is plastered on the outside of the body beneath and on either side of the oviduct, and covered with a viscid secretion which hardens almost immediately upon exposure to the air. While there may be some capacity for aspiration in the female organs, this certainly cannot be very powerful and the spermatozoa must make their own way to the seminal receptacle. It is not strange that a great many should get started in the wrong direction, follow up the oviduct, and even enter the ovaries. Here, in their wriggling, many force their way between or through the cells of the epithelium and eventually become inactive. Examination of the ducts of a female soon after copulation would probably show them to be motile.

Sedgewick (1901, pp. 18–19) notes the presence in Neotropical species of *Peripatus* of actively moving cilia in the epithelium of the duct from the receptaculum ovorum to the oviduct, and some zoologists have considered this another argument for excluding the animal from the Arthropoda. Fasten (1917) has demonstrated what he considers to be cilia in the vasa defferentia of several crustaceans. The region of the receptaculum seminis and the vasa deferentia are places in which the condition described above for *Stenopelmatus* might reasonably be expected to occur, if the epithelial cell-walls are not sufficiently strong to resist the entrance of the spermatozoa, and it is barely possible that Sedgewick and Fasten have encountered this condition in their material and have mistaken it for ciliated epithelium. It would be very easy to err in this, the true condition not being apparent except upon very careful examination, for which there would be no reason if there were not obviously something lacking in the explanation of the presence of cilia, as there is in *Stenopelmatus*.

In any case, I have thought it well to call attention to the condition as found, that this possible source of error may be guarded against.

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CONCERNING MELANDRYIDÆ (COLEOPTERA).*

By Melville H. Hatch.

The family Melandryidæ is changed to Serropalpidæ in the Junk-Schenkling *Coleopterorum Catalogus.* The genus *Melandrya* served as the type of *Melandryda* and *Melandryadæ* Leach 1817, so that it has distinct priority over *Serropalpus*, which did not serve as the type of a supergeneric group until *Serropalpes* and *Serropalpides* Latreille 1829.

Key to Nearctic Species of Melandrya Fab.

- A^1. Elytra septa- or octostriate; base of pronotum trisinuate; (**Melandrya** (s. str.); Mass. and Minn. to Iowa, Ind. and D. C................**striata** Say.
  - B^1. Sides of pronotum straight.
    - C^1. Black; legs in part paler....................................**type**
    - C^2. Legs and venter paler..........................ab. **bicolor** Melsh.
    - C^3. Legs, venter, pronotum and head paler; Mich., ab. **thoracicus** Melsh.
  - B^2. Sides of pronotum suddenly contracted before middle; black, pronotum tinged with rufous; N. Y................var. **excavata** Hald.
- A^2. Elytra quadricostate.
  - B^1. Base of pronotum trisinuate; pronotum widest in front of middle; second and third segments of antennae together longer than fourth; (type *E. connectens* Newm.).....................subg. **Emmesa** Newm.
    - C^1. Dorsum shining, smooth; pronotum transverse.
      - D^1. Piceous with clypeus, labrum, basal two segments of antennae, and apical portion of antennal and maxillary segments paler; pronotum distinctly swollen between basal impression and margin; hind angles of pronotum rounded; Conn. and Mich. to Ind. and Maryland..**labiata** Say.
      - D^2. Brownish with discal spot and apex of elytra and legs except apex of femora paler; pronotum not swollen, the basal impressions attaining nearly to margin; hind angles of pronotum more sharply rounded; Nfld., N. Y., Ont., Mich.....................**connectens** Newm. (*maculato* Lec.)
    - C^2. Dorsum not shining, with uneven surface bearing mixed brownish and golden pubescence; pronotum not transverse; N. Y...**blackmani** n. sp.†
  - B^2. Base of pronotum with scutellar lobe evenly rounded; pronotum widest behind middle; second and third segments of antennae together about equal to fourth; (subg. **Neoemmesa** nov.); black with clypeus and labrum paler; N. Y...........**noveboracensis** n. sp.
  - B^3. Base of pronotum straight; type and only species: *coccinea* Lewis, from Japan.................................subg. **Ivania** Lewis

Seidlitz (Naturg. Ins. Deutschl. V (2), 1898, p. 618, 619, 626) should be consulted for a key to genera of Melandryini

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*A contribution from the Department of Zoology of the University of Minnesota.

†Named after Professor M. W. Blackman, of Syracuse, its discoverer, to whom I am indebted for many favors.

(=Melandryæ Leconte and Horn) and the species of *Melandrya.* Csiki (Coleop. Cat., pars 77, 1924) should be consulted for bibliography.

I have expanded Seidlitz' conception of *Melandrya* to include all those species of Melandryini with costate elytra, and have indicated subgenera as shown. In addition to the Nearctic species, according to Seidlitz, my subgenus *Melandrya* includes *caraboides* L., the type of the genus, *alternatus* Mots., *dubia* Schall., *niponica* Lewis, and *mongolica* Solsk. My subgenus *Emmesa* includes *barbata* Lewis, *gloriosa* Lewis, *modesta* Lewis, *ordinaria* Lewis, and *rufipes* Gebl.

Seidlitz' determination of *labiata* Say has been accepted. *M. noveboracensis* n. sp. corresponds closely with Say's description, which does not mention the configuration of the base of the pronotum. In *labiata*, however, Say tells us that the pronotum is "with the lateral edge regularly arquated," which would seem to eliminate *noveboracensis*, in which the lateral margin is distinctly oblique anteriorly.

There seems to be some doubt as to the identity of *Emmesa connectens* Newm. Leconte regarded his *Melandrya maculata* as synonymous with it. Seidlitz denied this, and regarded *connectens* as the type and only species of *Emmesa*, which he defined by means of an evenly rounded non-emarginate scutellar lobe on the base of the pronotum. The two species cannot be separated on the basis of the original descriptions. My specimens conform to the Seidlitz definition of *maculata* Lec., which, for the present, I regard as synonymous with *connectens.* The possibility that they are not synonymous and that the true *connectens* is entirely unknown to me should not, however, be forgotten.

Melandrya (Emmesa) blackmani n. sp. Length, 12–13 mm., width across elytra 4–4.76 mm. Color throughout dark reddish brown; body covered with pubescence, which is nowhere so dense but that the ground color can be seen through it, consisting of a mixture of golden and reddish brown hairs. Head uniformly pubescent above. Antennæ 11-segmented, the apical nine segments finely but distinctly pubescent; third segment but little shorter than fourth. Pronotum not wider than long, without side margins except for a short distance at base; widest at apical two-fifths; apex arcuate; anterior angles entirely obsolete; base truncate, feebly trisinuate; hind angles rounded. Surface of pronotum uneven, median line distinct, with a furrow and several depressions on each side. Elytra quadri-costate, not wider behind, with golden pubescence more distinct along costæ, surface uneven, humeri tuberculate, elytral margins behind humerus sinuate. Elytra evenly and conjointly rounded at apex, with sutural and outer angle wanting. Legs with very fine pubescence. Fifth abdominal sternite broadly and deeply emarginate and narrowly paler along its apical margin.

Type and two paratypes: Cranberry Lake, N. Y., June 24, 1921. M. W. Blackman, collector. Type and paratype in collection of author. One paratype in collection of M. W. Blackman.

Melandrya (Neoemmesa) noveboracensis subg. et sp. nov. Length, 8 mm., width 3 mm. Throughout very finely pubescent and shining black except clypeus, labrum, basal two segments of antennæ, terminal two or three segments of tarsi, and last abdominal sternite, which are paler. Head moderately punctate. Second and third segments of antennæ together equal to fourth. Pronotum five-eighths as wide at apex as at base, widest just before base, thence feebly arcuate to apex, which is truncate. Base sinuate on each side, curving into an evenly rounded scutellar lobe. Disc coarsely punctate, median furrow nearly obsolete, lateral impressions extending about three-fifths of distance to apex, divided into two foveæ and separated from margin by a swollen portion of the pronotum. Scutellum rounded behind, the coarse punctures nearly contiguous. Elytra faintly quadri-costate, side margin gradually rounding into apex. Punctures of elytra coarser and more sparse than on pronotum. Last abdominal sternite very feebly emarginate.

Type, Cranberry Lake, N. Y., June 11, 1921. In collection of author.

Melandrya (Emmesa) colorata (Scudder), (*Silpha colorata* Scudder, U. S. G. S. Mon. XL, 1900, p. 44, Pl. V, Fig. 5) from the Upper Miocene of Florissant cannot be a silphid. Only the apical half of the elytra is preserved. The only living species with which I can compare the fragment is *Melandrya* (*Emmessa*) *connectens* Newm., from which it is separated by the failure of the apical spot to attain the apex of the elytra. Provisionally, therefore, I assign it to this subgenus.

This is only the third fossil melandryid at all adequately described. The first is *Abderina helmi* Seidlitz (l. c., p. 507, 577) from the Lower Oligocene of the Baltic Amber, whose structure and affinities are apparently as well known as any of the recent genera. The second is *Synchroa quiescens* Wickham, from the Upper Miocene of Florissant, Colorado. From the Baltic Amber Berendt (Organ. Reste. I, 1845, p. 56) listed an *Orchesia* and an *Hallomenus*, and Helm (Schr. Nat. Ges. Danzig, IX, 1896, p. 228) mentioned *Orchesia*, but these must be regarded as *incertæ sedis* until adequately described.

Canifa plagiata ab. **millikini** nov. Corresponds very nearly to the description of *plagiata* Melsh., except that the pronotum is blackish-fuscous. The pronotum is five-eighths as long as broad at the base, but I obtain this same measurement for specimens of *pallipes* Melsh. and *pusilla* Hald., so that Blatchley may be in error when he states that the pronotum is twice as wide as long in *plagiata*. The pronotum is impressed in front of the scutellum, but much more feebly than at the sides, where the impressions are distinctly foveolate.

Length, 2.5 mm.

Type: Macon Co., Ill., vi-2-1925, M. H. Hatch collector, in collection of author. Taken sweeping the herbage on the "back campus" of the James Millikin University, Decatur, after which I name it.

NEW ABERRATIONS OF TEMNOPSOPHUS AND PSEUDEBAEUS (MALACHIINÆ, COLEOPTERA).*

By MELVILLE H. HATCH.

Temnopsophus bimaculatus was described by Horn in 1872 from a unique from Louisiana in the Ulke collection. As nearly as I am able to ascertain, the genus has not been mentioned in the literature since except by Schwarz, who, in 1878, recorded Horn's species as common in Florida and described *T. impressus*.

In July, 1922, the author took a series of thirteen specimens in the vicinity of Ann Arbor, Michigan, which, on the basis of Horn's description, seemed to be distinct from his species. However, a series of specimens lent me by Mr. E. C. Cresson, of the Philadelphia Academy of Natural Science, showed that the differences are not specific.

Key to Forms of Temnopsophus Horn.

A^1. Base of elytra feebly or not impressed; length, 2-2.5 mm.; La., Ga., Fla., Ill., Mich.. **bimaculatus** Horn.
    B^1. Lateral spot of elytra not attaining humerus.
        C^1. Apex of elytra not pale; La., Ga., Fla., Mich................ **type**
        C^2. Apex of elytra pale; Ill.................. ab. **quadrimaculatus** nov.
    B^2. Lateral spot of elytra attaining humerus; Mich., Fla.. ab. **estelle** nov.
A^2. Base of elytra distinctly transversely impressed; Fla... **impressus** Schwarz.

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*Contribution from the Department of Zoology of the University of Minnesota.

The type ♂ and paratype ♀ of ab. *quadrimaculatus* are in the collection of the Philadelphia Academy of Natural Science. The type (♂, AA20 Washtenaw Co., Mich., vii–26–1922) and nine paratypes (1 ♂ and 8 ♀, with same data as type, 1 ♀, AA15, Washtenaw Co., Mich., vii–25–1922) of ab. *estelle* are in the collection of the author and two paratypes (1 ♀, same data as type, and 1 ♀ from Fla.) are in the collection of the Philadelphia Academy of Natural Science.

The Michigan specimens of *bimaculatus* Horn average slightly longer than the southern specimens, most of the Michigan specimens being very nearly 2.5 mm. long, while most of the southern specimens are about 2 mm. long. The antennæ throughout the species vary from those with the first 3 to 5 segments distinctly paler to those in which only the last 1 to 3 segments are distinctly darker. The pronotum is widest at about two-fifths its total length from the base, strongly rounded cephalad, with the base feebly emarginate and paler. In some specimens, perhaps from immaturity, the entire pronotum is somewhat lighter in color and the paler base is not evident; in others the paler base is reduced to a fine marginal line. In only one of the specimens at hand (the type of ab. *quadrimaculatus*) does the lateral elytral spot conform closely with Horn's figure of the type. In the others the spot extends towards the humerus, but is separated from it by a narrow darker area except in ab. *estelle*. The humeri are at best very feebly distinct, and the elytra at base are only slightly wider than the base of the pronotum. The legs vary from testaceous to those with the femora and tibiæ distinctly dark. The sexual differences are such as are described for *T. impressus* Schwarz. The anterior tarsi of the ♀ are 5-segmented.

The present opportunity is taken to announce a new aberration of *Pseudebaeus apicalis* Say to which the name **nigroapicalis** nov. is given. It is distinguished from the type by having the apical margin of the pronotum a dusky black. Type ♂ and 3 paratypes ♂ and 2 ♀, Macon Co., Ill., V-30–1925. M. H. Hatch; in collection of author. Taken sweeping vegetation in Decatur.

A BIONOMICAL STUDY OF THE CLUSTER FLY POLLENIA RUDIS (FAB.). (DIPTERA, CALLIPHORIDÆ).*†

R. M. DeCoursey,
University of Illinois.

The cluster fly, *Pollenia rudis* (Fab.), has been an interesting species to the entomologist for a number of years. It is a common fly in most parts of the United States and yet, until recently, very little was known about it. The species is the type of the genus *Pollenia* and is by far the best known species of the genus. The cluster fly is ordinarily observed in large numbers only in the autumn and spring. It is not abundant during the summer. The species becomes troublesome in houses in the autumn while seeking hibernation and again in the spring at the close of the hibernating period.

REVIEW OF LITERATURE.

Robineau-Desvoidy (1863) records the fact that clusterflies became common in the autumn and entered houses when it became cold. He supposed that they laid their eggs in decomposing animal or vegetable matter. Schiner (1862–1864) observed that they were common on walls and on the trunks of trees where they were exposed to the spring sunshine. Schiner knew nothing of the life history of the fly.

Dall (1882) and Riley (1882) each reported a severe infestation in houses. Dall closes his report in this significant manner "Words fail to describe their general depravity; it is beyond expression. If you wish to be happy, be sure you don't introduce cluster flies into your family."

Although there are many reports of infestations there apparently was no investigation concerning the life history of the fly until Keilin published his first account in 1909, when he announced that the larvæ of *Pollenia rudis* (Fab.) were parasitic in the general body cavity of *Helodrilus* (*Allolobophora*) *chlo-*

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*An abstract of a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Entomology in the Graduate School of the University of Illinois, 1927.

†Contributions from the Entomological Laboratories of the University of Illinois, No. 117.

roticus (Sav.). This short article was followed in 1915 by a detailed account of the life history of the fly with an especial study of the larvæ.

Briefly, Keilin's results show that the larvæ of *P. rudis* live as parasites in the general body cavity of *H. chloroticus* (Sav.) or *H. roseus* (Sav.). The female fly lays eggs in the soil toward the end of August or the beginning of September. The larvæ, which hatch four to six days later enter the earthworm by the male genital orifice and pass into the body cavity of the genital segments. The larvæ are probably able to enter while the worms are in copula. The larvæ lie dormant in the body cavity from September or October until the following April or May when they become active and migrate to the anterior end of the worm. When a larva arrives at the prostomium, its posterior spiracles are exposed to the air and it begins feeding upon the anterior segments of the worm. Six to ten days later the larva molts and passes to the second instar.

The second instar larva feeds for nine more days and passes to the third and last instar. At this stage it begins to feed aggressively on all the tissues of the host. As its volume increases it distends the body of the worm and becomes more and more exposed as it progresses toward the posterior end of the worm. It finally leaves the worm which is generally still living, and pupates in the soil. The third instar lasts nine or ten days. The adult emerges from the pupa after thirty-five to forty-five days.

Webb and Hutchison (1916) attempted to verify Keilin's work, in America. They found no indications of a dormant period during which the larvæ remained practically motionless in the body cavity of the worm. Their study of summer generations indicated a much shorter period of development, according to the following data: egg stage, 3 days; larval stages, 3–22 days; pupal stage, 11–14 days. The total period of development was found to be 27–39 days. They reached a tentative conclusion that there were four generations in the latitude of Washington, D. C.

Two papers dealing with the biology of *Pollenia rudis* (Fab.) were published in 1924. The first, by Barnes (1924), is characterized by too hasty conclusions drawn from insufficient evidence. He states in his summary that "The presence of worms in the soil is necessary for oviposition." We have found that the flies oviposit readily when no earthworms are present in the soil. Barnes also states that "Fertilization takes place before hibernation, although males do survive the winter." Our examination of spermathecæ of hibernating females has never revealed any sperms. Copulation of the hibernating generation has been observed by us to take place in the spring.

The article by Garrison (1924) gives several rearing records of *P. rudis*. The flies were allowed to lay eggs on the soil in cages. As soon as eggs were found all the flies were removed and a certain number of earthworms, *H. chloroticus*, were placed on the soil. A daily watch was kept for the emergence of adults.

Garrison was able to secure a small emergence by this method. In the worms examined, the larvæ were found in different parts of the body of the worm, and did not appear to be confined to any particular region.

APPARATUS USED.

In the present work, flies were caught in especially designed traps similar to the cone-shaped traps on the market for trapping house flies, but provided with a second cone at the top of the trap, which opened into a small wire cylinder 2½ inches in diameter and 6½ inches high. The cylinder screwed into the frame of the trap. The flies collected in the cylinder at the top of the trap and were held there by the second cone which they had passed through. Duplicate cylinders were made for each trap to enable one to make collections quickly.

Screen wire cages with metal frames were used for rearing the flies. Soil was placed on the floor of the cage to a depth of about three inches. The soil was kept moist and the flies laid their eggs in it quite readily. A cylindrical screen wire cage which may be set over flower pots is very convenient.

DESCRIPTION OF LIFE STAGES.

The paper white eggs of the cluster fly are about 1 mm. long and 0.3 mm. in diameter (Plate XX, Figs. 1 and 2). The ventral side of the egg is convex while the dorsal side is flat or slightly concave. Two carinæ extend along the dorsal side of the egg almost to the posterior end. The surface of the egg with the exception of the two ridges and the groove between them is finely etched into irregular figures.

The larvæ of the cluster fly are legless maggots and have the characteristics of the larvæ of the higher families of Diptera (Plate XX, Fig. 3).

The first instar larvæ are 1 mm. to 1.5 mm. long and 0.2 mm. to 0.25 mm. wide. They are nearly transparent and the organ systems can be seen by reflecting light through the body. The dark-colored, pharyngeal skeleton of the head shows very distinctly. The cuticular spines are also nearly transparent and difficult to see even with the microscope.

Keilin (1915) has made a detailed study of the larvæ of this species; the reader is referred to his descriptions.

The pupa of the cluster fly develops within the larval skin as do the other Calyptrate Muscids (Plate XX, Fig. 4.). The larval skin becomes a tough, brown-colored, puparium for the developing pupa. The pupal case of the cluster fly is 7 mm. long and 2.5 mm. wide. The form of the antennæ, the anterior spiracles and the plates of the posterior spiracles of the larva, may be seen on the pupal case. Pupation occurs in the soil.

The adult fly is somewhat larger than a housefly (Plate XX, Fig. 5.). The female is slightly larger than the male. The eyes of the female are dichoptic, while those of the male are holoptic. As a whole, the fly has a non-metallic, dark gray color. When at rest it overlaps its wings, which gives it a linear appearance.

The antennæ are rather small, the proximal segments are of a reddish color. The parafacials, or genæ, are setose down to the ventral margin of the eye.

The adult is easily recognized when it is in the newly emerged condition, by the coat of curly yellow hair on the dorsum of the thorax. This pile, however, is easily rubbed off. The thorax is without distinct stripes and there are two pairs of anterior acrostical bristles, two anterior and three posterior dorsocentrals, one posthumeral and one presutural. The fourth longitudinal vein of the wing, (Media 1 and 2), is sharply bent. The abdomen is dark grey with irregular lighter patches.

P. rudis is widely distributed in both the Old and the New World. In America it has been reported from all the provinces of Canada and is generally present throughout the United States with the exception of the states bordering on the Gulf of Mexico. It is known to be present from coast to coast between 35 and 45 degrees N. latitude.

THE HIBERNATING GENERATION DURING THE SPRING MONTHS.

The first warm days of early spring are marked by the appearance of the cluster flies. They often emerge when the air is so cold that they are unable to fly. If there is snow on the ground they are all the more conspicuous crawling about on the snow, but they soon become imbedded in it and die.

When the weather is warm enough to permit flight the adults may be found feeding on fruits, around garbage containing fruit or other sweet liquids. They are fond of the sap from trees and shrubs and are common in cornfields on warm spring days where they are attracted to the moist pith of the cornstalks. They also come to traps baited with apple or banana.

In the spring the flies often become a nuisance in houses. The increasing warmth of the spring days induces activity and if the hibernating quarters have been in the walls of a house or around the window frames, the flies may emerge inside the house instead of on the outside. Just as they become a nuisance in the fall while seeking hibernating quarters, they are also bothersome in the spring as they try to escape.

It is interesting to note that while the flies collected around buildings during the latter part of February were almost exclusively males, collections from fields of corn stubble showed a great majority of females. Females were also in the majority when taken in traps at this time.

COPULATION.

On February 23, and 24, 1927, thirteen pairs of *P. rudis* were observed in copula. The time or method of copulation has not previously been recorded. All the cases of copulation observed took place in the warm sunlight on the protected side of large buildings. The temperature was 62° F. in the shade, and 80° F. in the sunlight.

The actual meeting of the male and female is difficult to observe. Apparently the female flies near a group of males as they are sunning themselves on the ground. There is a sudden rush among these males and the successful male comes to rest with the female, on the side of the building or on the ground. The pair assume the characteristic pose of copulating muscids; the male rests on the back of the female, the forelegs between her wings, the genital appendages at the tip of the abdomen clasping the ovipositor of the female in which the penis is inserted.

The female is able to walk or fly with the male while they are still in copula, but does not ordinarily do so unless disturbed. Large males were observed mating with small females and vice versa. The length of time in which the flies remained in copula varied from 3 to 15 minutes in cases observed.

OVIPOSITION.

P. rudis was observed ovipositing in the field the afternoon of March 30, 1927, a little more than a month after copulation had been observed. Copulation of the hibernating generations occurs on the first warm days of early spring but oviposition may be greatly retarded by unfavorable weather conditions. The day on which the act of oviposition was observed was bright and warm with a temperature above 80° F. at the surface of the ground where oviposition occurred. The plot of ground was a garden of black loam soil which had been cultivated the preceding summer.

Several females, probably a dozen, were observed running hurriedly around over the ground. One female was selected and its movements followed in detail. Upon coming to a suitable spot, the fly first, apparently, investigated the place. Then quickly turning around, the ovipositor was inserted in the soil. The female usually backed up slightly in order to push the ovipositor further into the soil.

The act of oviposition took only 15 to 30 seconds after the place had been selected. Often two or three eggs were laid within an inch of each other, then the female usually flew a foot or more away before depositing another egg. This method of oviposition gives considerable distribution of the eggs and must necessarily be of advantage to the young larvæ in locating their hosts.

Individual females confined in cages have laid as high as 97 eggs in one evening. Ordinarily females in confinement do not lay their eggs freely and the number of eggs laid by unconfined females is probably somewhat greater. Confined females will oviposit whether there are earthworms present in the soil or not. There is apparently no oviposition stimulus derived from the presence of earthworms.

While the females will oviposit freely on various types of soil and upon fresh cow dung, we have never obtained any oviposition upon decaying flesh or decaying vegetables.

The most common earthworms present in the soil where the eggs were deposited, were, *Lumbricus terrestris* Linn. Muller, *Helodrilus roseus* (Sav.), and *Octolasium lacteum* (Orley). *Helodrilus* (*Allolobophora*) *chloroticus* (Sav.) was not present. This species at Urbana is quite limited in its distribution and has been collected only from certain places along the banks of the drainage ditch.

The relation of the larvæ of *P. rudis* to their host is not clear in all its details. The larvæ apparently feed upon earthworms, at least occasionally, but no one in America has been able to verify the type of parasitism described by Keilin (1915).

Since *H. chloroticus* was not present in the soil where oviposition was observed in the field, other earthworms apparently act as hosts. We have observed first instar larvæ of *P. rudis* feeding upon live worms of the species *H. roseus* in the laboratory, but in no case have they entered entirely inside the worm. They have always fed with the posterior spiracles exposed. They have penetrated the worm at different places far back of the clitellar regions, as far back as the 87th segment. The larvæ do not appear to be constant parasites for they frequently withdraw themselves from the wound and crawl about over the worm. Larvæ have been observed to feed upon crushed earthworms as long as they remain fresh. Two larvæ were observed attacking from the outside, that is, not in the manner described by Keilin.

In the laboratory, larvæ have fed readily on earthworms of the species *H. roseus* but have refused to feed upon *H. chloroticus* when introduced in the same manner. Adults have been reared from soil containing species of earthworms commonly found in this locality. Earthworms of the species *H. chloroticus* were collected and examined every two weeks during the summer months for two years but no parasitized earthworms were found. These earthworms after examination were placed in soil in glass jars to permit emergence of adult flies, but none emerged. Keilin (1911) found the number of parasitized worms to be quite large. He makes the following statement; "In 107 worms dissected I found 74 parasitized by 87 larvæ." It appears, then, that *H. chloroticus* is not the principal host of *P. rudis* larvæ in this locality.

All attempts to feed larvæ on material other than live earthworms have failed. The larvæ have failed to survive when provided with cow dung, horse manure, loam soil, clay soil, grass sod, decaying roots of grass in soil, decaying wood, decaying meat and dead earthworms. Adults laid eggs on all these materials except decaying meat and dead earthworms.

We have secured no emergence of adults from manure containing *H. foetidus* and examinations of manure worms has never shown any parasitism by the larvæ. Out of hundreds of earthworms of various species examined, we have never found any second or third instar larvæ attached to a partly devoured earthworm as described by Keilin. Many injured earthworms are found, however, and it seems probable that the larvæ of *P. rudis* feed only intermittently upon earthworms and that when not feeding they are free living in the soil.

THE SUMMER GENERATIONS.

The cluster fly is not abundant during the summer months. If an especial effort is made they may be found but otherwise they would probably not be observed. Daily records of flies caught in traps indicate that there are probably four generations per year at Urbana.

The hibernating generation dies off by the middle of April in the latitude of central Illinois and the first generation begins to appear during the latter part of May. This is not usually an abundant generation but flies may be taken in traps during the latter part of May and the first week or two of June.

The flies then practically disappear until about the middle of July when the trap records show a steady increase until the end of the month. This is regarded as the second generation. From the middle of August throughout September a few flies are nearly always present. It is possible that by later summer, due to individual variation in the length of the life cycle the adults are constantly emerging and no distinct generation can be identified. The hibernating generation makes its appearance near the first of October and is regarded as the fourth generation.

THE HIBERNATING GENERATION DURING THE FALL AND WINTER.

The adults of the hibernating generation have a newly emerged appearance and usually have a glistening coat of yellow pile on the dorsum of the thorax. The ovaries of the females are undeveloped. The abdomen of both males and females is usually filled with fat. This is the most abundant generation of the year.

As the weather becomes colder the flies are active only during the warmest part of the day. At night they hibernate in buildings or outside under surface debris or other sheltered places.

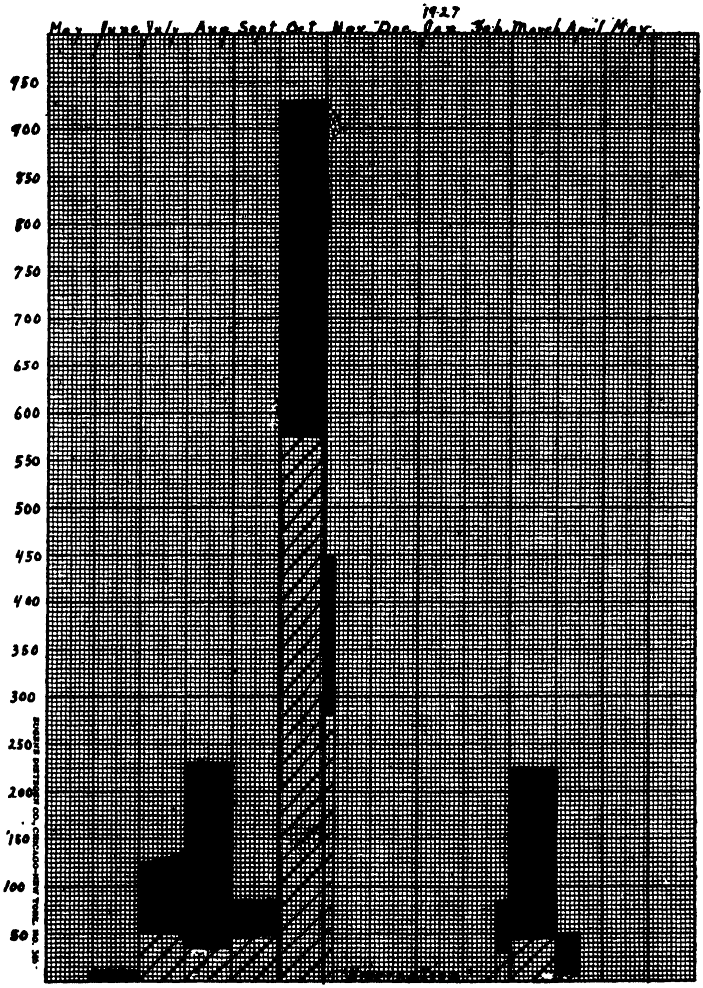

TABLE I.

A graph showing a monthly record of the number of cluster flies taken in traps during the year 1926–27. Solid black = females. Cross-lined = males.

They have been found to be especially common in cornfields, where they are found under the leaf sheath of the cornstalk. While the adults that hibernate in buildings are often more conspicuous, it seems certain that cluster flies also hibernate in the open in considerable numbers.

Cluster flies may be kept over winter in active condition in the laboratory if fed on decaying fruits and provided with water. Adults in confinement were kept over winter in hibernation by bringing them into the warm laboratory at intervals to be fed. Adults sealed in a box and kept in hibernation from November 11, until March 4, were able to pass the winter without food or water although adults in natural hibernation commonly feed when the weather permits.

Experiments with adult cluster flies in which both temperature and light factors were controlled show, that the adult is negatively phototropic at temperatures below 50° F. It is positively phototropic at temperatures above 50° F.

The negative phototropism was not disturbed by variations in temperatures below 50° F. The adult, at hibernating temperatures, crawled to the dark end of an experimental tube even though it was eight degrees colder than the light end of the tube. At hibernating temperatures the cluster fly exhibits a positive thigmotropism. In nature, the fly is commonly observed wedged into corners along the weatherboarding or window frames of houses when the weather is cold. In experiments, positive thigmotropism was observed when the temperature was below 50° F.

Ten live males and ten live females of the hibernating generation showed an average weight of 23.66 mg. for males and 28.23 mg. for females. The greater weight of females is accounted for by the unusual amount of fat stored in the abdomen.

THE MALE AND FEMALE REPRODUCTIVE SYSTEMS.

The reproductive system of the male cluster fly consists of two testes, a pair of accessory glands, the vas deferens, the ejaculatory sac, the ejaculatory duct, and the penis (Plate XXI, Figs. 1, 2).

The testes (T)* are elongated organs, much smaller than the ovaries of the female and are salmon colored. They lie dorsally on either side of the median line in the fourth segment of the abdomen. A duct from each testis opens into the vas deferens.

Internally the testis is a simple follicle. Stained sections of follicles show a series of zones in which the male germ cells are found in different stages of development. Testes from hibernating males, examined during the winter months, contained germ cells in various stages of development, while ovaries of females examined during the same time were found to be practically dormant. The testes apparently produce sperms continuously while the ovaries after remaining dormant all winter undergo rapid development in the spring.

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*Letters refer to Figures in Plate XXI.

The accessory glands (AG) lie between the testes. They are not convoluted as in many insects, but are long slender glands opening by a short duct into the vas deferens.

The vas deferens (VD) leads to the ejaculatory sac (ES) which is ovoid in shape. A dark colored, elongate sclerite may be clearly seen within the sac. The sac has a thick muscular wall. The ejaculatory sac probably functions as a pump to drive the seminal fluid through the slender ejaculatory duct (ED) which leads to the penis (P).

The male genitalia of *P. rudis* are shown in some detail because we believe they may be useful in taxonomic work regarding the genus *Pollenia.* The description of *Pollenia obscura* (Bigot) is termed unrecognizable by some writers. The identity of the species might be clearly established by a comparison of the genitalia with that of *P. rudis.*

The penis lies between the styles and cerci (Plate XXI, Fig. 2). During copulation, the ovipositor of the female is partially distended and is firmly clasped by both the styles and cerci while the penis is inserted in the vaginal opening.

The reproductive system of the female cluster fly is composed of a pair of ovaries with their oviducts, a pair of colleterial glands, three spermathecæ, the vaginal tube and the ovipositor (Plate XXI, Figs. 3, 4, 5).

The ovaries (O) in hibernating females during the winter months are nearly oval bodies lying in the fourth abdominal segment. They are concave on the dorsal side and convex on the ventral side. Each ovary contains a number of ovarioles, usually about one hundred.

In the dormant ovary of the hibernating female, each ovariole contains a very immature egg. The eggs in the ovarioles remain at this stage with little change from October till the latter part of February in this latitude. The warm days which come at the latter part of February or early in March, awaken the flies to activity for a few hours during the warmest part of the day. It is then that the eggs in the ovarioles begin to enlarge. The most mature egg enlarges rapidly and the ovariole expands to accomodate the growth of the egg. In years when there is an early spring many females are ready to lay eggs by the middle of March at Urbana.

At the time of egg laying the ovaries occupy the greater part of the abdomen, reaching anteriorly to the air sacs. They are separated from the body wall by a thin layer of fat which is reduced to a minimum at this time.

The oviducts (Plate XXI, Fig. 3, OD) unite shortly after leaving the ovaries and extend as a single tube to the vagina (V). Ducts from the colleterial glands (CG) and the spermathecæ (S) enter the vagina dorsally. The colleterial glands are long tubes lined by large epithelial cells. They probably function partly to furnish the secretion which gives the shiny varnished appearance characteristic of newly laid eggs.

There are three spermathecæ, two on the right and one on the left (Plate XXI, Fig. 4). The spermathecæ and their ducts have an epithelial covering. The capsules themselves are chitinized and are dark brown in color, but the ducts are colorless. Both the spermathecæ and their ducts are lined with a striated cuticular intima, that gives the ducts somewhat the appearance of tracheæ. The intima is colorless and faintly striated in the ducts but in the spermathecæ it is plainly ridged and is a dull yellow color.

Examination of the spermathecæ of hibernating females has never revealed any sperms. The spermathecæ were placed on a slide in physiological salt solution and crushed under a cover glass. Females after copulation have the spermathecæ filled with sperms which are readily demonstrated by this method. We conclude, then, that copulation does not take place in the fall.

The ovipositor when fully extended is about 1.7 mm. long (Plate XXI, Figs. 5, 6). It is used to push the eggs into the soil during oviposition, and is also important in receiving the seminal fluid of the male during copulation. To the taxonomist, it may prove to be of specific value as the genitalia of insects are more thoroughly studied.

NATURAL AND APPLIED CONTROL.

The weather is the most imporatnt factor in natural control of the cluster fly. An unusually cold winter kills great numbers of adults. Heavy rains probably drown a great many larvæ in the soil.

The chief offence of the cluster fly is that it is a general nuisance in the house. The flies usually enter around the window frames, under shingles, weatherboarding, or through cracks in the foundation. Once inside the house, the flies crawl sluggishly over the walls and often drop into food on the table. They are often rolled up under window blinds and leave unsightly greasy spots where they are crushed.

Recent reports of severe infestations have been wholly lacking. Probably modern methods of constructing houses are solving the problem. Tests of some of the commerical sprays on the market for the control of the house fly in houses, have shown that they may also be applied against the cluster fly. It is good practice to keep all rooms open and well lighted in the fall.

ACKNOWLEDGMENTS.

I wish to express my gratitude to Prof. C. L. Metcalf for his unfailing interest and guidance in the preparation of this work. I also wish to thank Prof. W. P. Hayes, Prof. W. V. Balduf and Dr. R. D. Glasgow for their valuable criticism and many helpful suggestions. Prof. Frank Smith and Mr. B. H. Hill have aided in the identifications of earthworms.

SUMMARY.

1. A bionomical study of the cluster fly is presented.
2. Both males and females hibernate during the winter months and become active again in the spring.
3. Examination of the spermathecæ of hibernating females shows that they do not contain sperms during the winter. Copulation, therefore, does not take place in the fall.
4. Copulation of cluster flies was first observed on February 23, at Urbana, Illinois, and is recorded and described for the first time.
5. Oviposition of cluster flies in the field on March 30, is also recorded and described for the first time.
6. The earthworm, *Helodrilus chloroticus* (Sav.), formerly considered the principal host of the larvæ of the cluster fly, is not the principal host in this locality.
7. The first instar larvæ of the cluster fly refused, in the laboratory, to attack *H. chloroticus* in the manner described by previous workers.
8. Adults of the cluster fly emerged from soil in which *H. chloroticus* was not present.
9. The first instar larvæ of the cluster fly, in the laboratory, readily attacked the earthworm *Helodrilus roseus* (Sav.) as an intermittent parasite or predator.
10. The manure worm, *Helodrilus foetidus* (Sav.) has never been found parasitized by the larvæ of the cluster fly, and no adults have emerged from manure in which *H. foetidus* was common.
11. Attempts to rear larvæ of the cluster fly as a scavenger in the soil, dung, or decaying animal or vegetable matter, have uniformly failed.

12. The adult fly of the hibernating generation ordinarily exhibits a positive phototropism, except when seeking hibernation.

13. At temperatures below 50° F., the adults exhibit negative phototropism, which functions when seeking hibernation.

14.. The cluster fly exhibits positive thigmotropism at temperatures below 50° F.

15. The adult hibernates in cornfields under the leaf sheaths of cornstalks, beneath bark, and under surface refuse, as well as in buildings.

16. Artificial hibernation experiments have shown that adults of both sexes may successfully hibernate during the winter without food or water, although adults in natural hibernation commonly feed when weather permits.

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*Minor references have been omitted.

EXPLANATION OF PLATES.

PLATE XX.

Fig. 1. Lateral view of egg, × 35.
Fig. 2. Dorsal view of egg, × 35.
Fig. 3. Lateral view of larva, × 50.
Fig. 4. Dorsal view of puparium, × 7.
Fig. 5. The adult; dorsal view, × 10.

PLATE XXI.

Fig. 1. The male reproductive system, × 40. AG, accessory glands; ED, ejaculatory duct; ES, ejaculatory sac; P, penis; T, testis; VD, vas deferens.

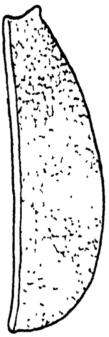
Fig. 2. Dorsal view of penis and surrounding structures, × 40. C, cerci; P, penis; L STY, left style; R STY, right style.

Fig. 3. The female reproductive system; dorsal view, × 17. CG, colleterial glands; O, ovaries, OD, oviduct; OV, distal end of ovipositor; S, spermatheca; V, vagina.

Fig. 4. The spermathecæ; dorsal view, × 65. D, duct; S, spermatheca.

Fig. 5. Dorsal view of ovipositor, × 17. C, cerci; SP, suranal plate; 6, 7, 8, 9, body segments included in ovipositor.

Fig. 6. Ventral view of ovipositor, × 17. ASP, anterior spiracle; PSP, posterior spiracle; CL, club; SUB P, sub-anal plate.



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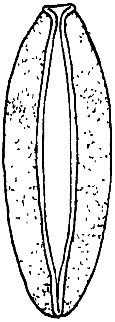

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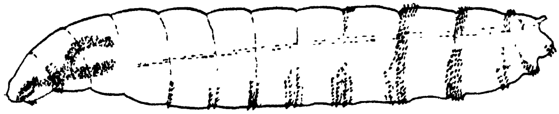

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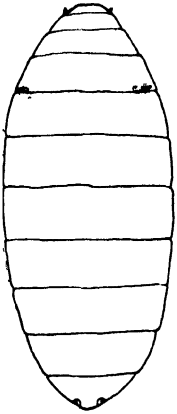

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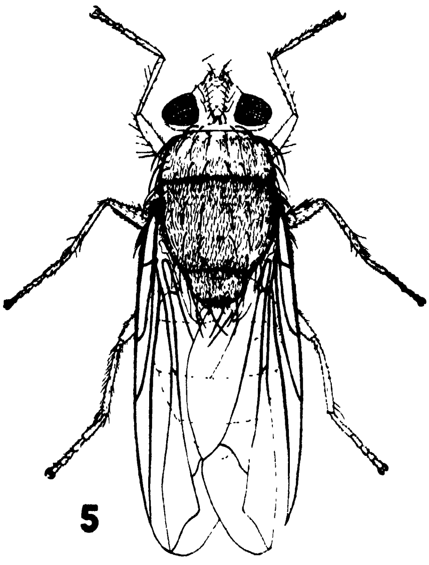

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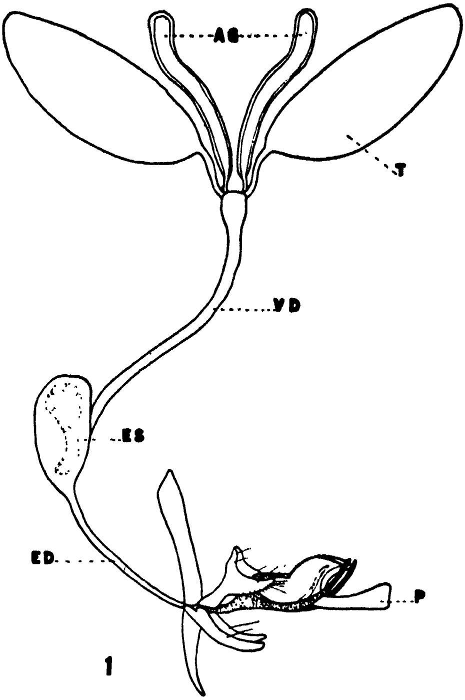
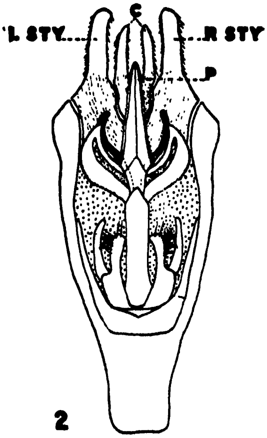
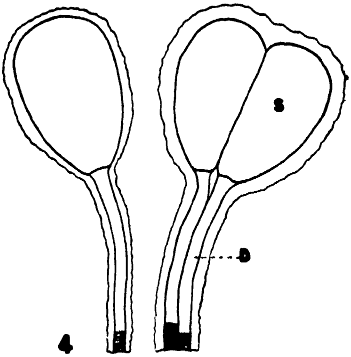
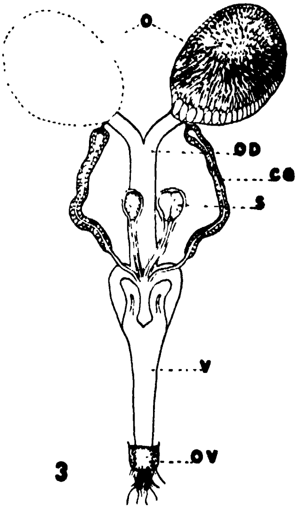
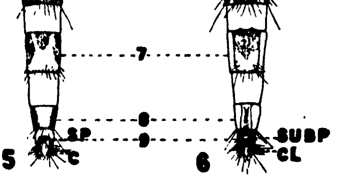










R. M. DeCoursey.

ENALLAGMA AND TELAGRION FROM WESTERN FLORIDA, WITH A DESCRIPTION OF A NEW SPECIES.

By C. Francis Byers,
Cornell University.

The author received a collection of Odonata from Western Florida made during the first weeks in April 1927. The collection, though small, proved to be a very interesting one, the following list and notes resulting from a study of Enallagma and Telagrion.

1. **Enallagma weewa,** n. sp.

Male: Color in dried specimens, light tan and metallic-greenish black, becoming violet-gray and pruinose in old specimens.

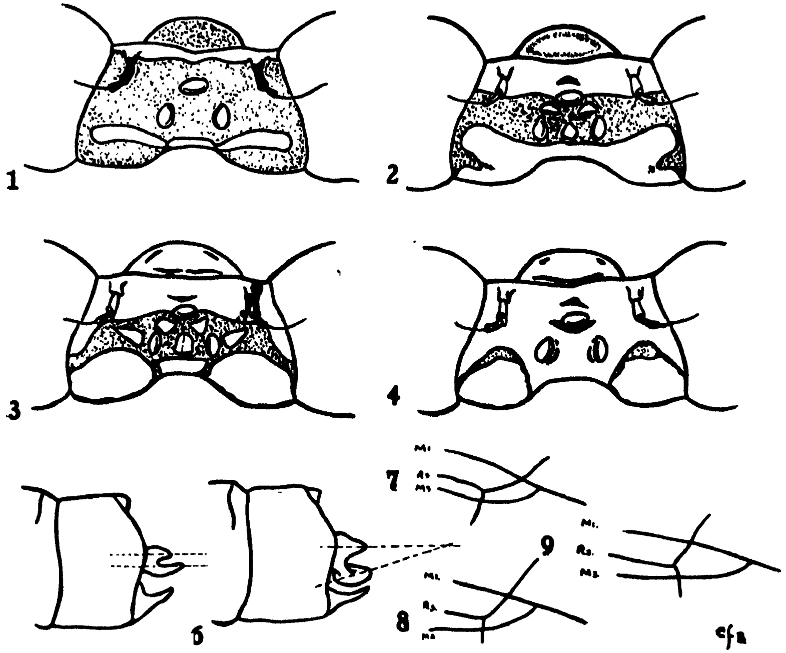
Mouth-parts, genæ, postgenæ and occiput pale. Mandibles pale, with a black basal spot. Basal half of labrum and post clypeus black. Pale transverse frontal band narrow, hardly reaching to the bases of the antennæ. Remainder of frons, the vertex and the antennæ, black. Pale postocular spots linear, narrowly joining, or separated from, the pale, postocellar stripe, not connected with the pale color of the postgenæ and occiput, (Fig. 1).

Prothorax predominantly black, most of the anterior lobe, the sides, a pair of lateral spots, a dorsal twin spot of the middle lobe, and the posterior margin of the hind lobe, pale. Thorax with the mid-dorsal carina broadly brown, separating the usual wide mid-dorsal dark stripe into two narrower stripes. The humeral dark stripe very irregular and split longitudinally in the middle of its length so that almost the whole of the mesopleural suture is pale. The pale antehumeral stripe narrow. A black basal streak on the interpleural and metapleural sutures, that on the latter usually prolonged as a narrow line to the base of the posterior legs. Remainder of the thorax pale. Legs pale, femora with longitudinal dark stripes. Wings with M_2 arising nearest the fourth postnodal cross-vein in the hind pair, the fifth in the fore pair, 11–12 postnodal cross-veins in the fore wings, 10–11 in the hind wings.

Abdomen pale, segments 1–8, inclusive, with the dorsum entirely metallic black, except for narrow basal rings on 3–6. Segment 9 entirely pale except for a narrow apical line of black. Segment 10 entirely black.

Superior abdominal appendages black, shorter than 10, bifid, with no tubercle between the arms. The upper arm short, subtriangular, the lower oval and semi-rotated under the upper, so that a line drawn through its long axis would meet a similar line drawn through the upper arm, at an acute angle (Fig. 6), otherwise similar to *E. exsulans* (Fig. 5).

Female: Similar to the male, except segment nine of the abdomen has a triangular basal spot on the dorsum, the apex of the triangle directed toward the apical margin, which it nearly touches. Segment 10 entirely blue. A heavy ventral spine on the apical margin of abdominal segment 8.



ENALLAGMA AND TELAGRION.

Fig. 1. Head of *Enallagma weewa* n. sp. Shows usual extent of black pigmentation in Enallagma.
Fig. 2. Head of *Enallagma laurenti*, female. Shows reduced condition of pigmentation in Enallagma.
Fig. 3. Head of *Enallagma pallidum*. Shows intermediate condition of pigmentation between Enallagma and Telagrion.
Fig. 4. Head of *Enallagma daeckii*. Shows extreme reduced pigmentation.
Fig. 5. Male superior appendages of *Enallagma exsulans*. Dotted lines drawn through long axis of the arms.
Fig. 6. Male superior appendages of *Enallagma weewa* n. sp. Dotted lines drawn through the long axis of the arms.
Fig. 7. *Enallagma daeckii*. Partial venation of the fore wing.
Fig. 8. *Enallagma pallidum*. Partial venation of the fore wing.
Fig. 9. *Enallagma antennatum*. Partial venation of the fore wing.

Dimensions: Total length, male 38 mm.; female, 38 mm.; length of abdomen, male, 31 mm.; female, 30.5 mm; fore wing expanse, male, 42 mm.; female, 46 mm.; length of hind wing, male, 19 mm.; female, 21 mm.

Holotype. One male, Chipola Lake, Wewahitchka, Gulf Co., Fla. (No 804.1, Cornell University Coll.). *Allotype.* One female, Kathwood, Aiken Co., South Carolina. (No. 804.2, Cornell University Coll.). *Paratypes.* Two males and one female, Kathwood, S. C. (University of Michigan Coll.). One male, Chipola Lake, Fla. (Byers Coll.). Two males, Kathwood, S. C. (No. 804, Cornell University Coll.). One male, Ogelthorpe, Georgia. (No. 804, Cornell University Coll.).

Enallagma weewa, named after Wewahitchka, Florida, the type locality, is closely related to *Enallagma exsulans*, with which it has been confused for years. At first glance the appendages bear a resemblance to *E. exsulans* it is only when the two specimens are compared side by side that one sees that in *exsulans* the lower arm of the superior appendages is not semi-rotated under the upper, so that a line drawn through its long axis would be parallel with a similar line drawn through the upper arm, and not at angles to it, as in *weewa*, (Figs. 5–6). In coloration the differences between *weewa* and *exsulans* are slight, and confined in the most part to the head. In *weewa* the labrum has the basal half black, the mandibles have a black basal spot, the pale transverse frontal band is narrow, not reaching the bases of the antennæ, and the postocular spots are very narrow; in *exsulans* the labrum has a black basal dot only, mandibles are pale with no basal black, the pale transverse frontal stripe reaches a little beyond the bases of the antennæ, and the postocular spots are generally semi-rounded and wider than in *weewa*. These differences are slight and subject to fluctuation, or may even be eliminated in live material. In size *weewa* (length 38 mm.) is a larger Damselfly than *exsulans* (32–35 mm.).

Weewa occurs in South Carolina, Georgia and Florida. The material taken by Mr. Jesse H. Williamson, at Kathwood, South Carolina; by Dr. J. C. Bradley, at Oglethorpe, Georgia; and by Dr. Needham in Florida, are all of this species, as far as the material represented in the Collections of the University of Michigan and Cornell University have been examined. Probably the species is universal in the South-Eastern United States, where it replaces *exsulans*.

2. **Enallagma dubium** Root. Four males, Bull Pond, Tallahassee, Leon Co., April 12. One male, Chipola Lake, Gulf Co., April 9.

This species was described by Dr. F. M. Root (1924, Ent. News, 35:321), as new, from Lee County, Georgia. This is the first record, as far as I know of its capture since its description. A new Florida record.

3. **Enallagma pollutum** (Hagen). Twelve males, 3 females, Bull Pond, Tallahassee, Leon Co., April 12. One male, Chipola Lake, Gulf Co., April 9.
4. **Enallagma signatum** Hagen. One male, Chipola Lake, Gulf Co., April 9. (Three males, one female, Spring Creek, Decatur Co., Georgia).
5. **Enallagma sulcatum** Williamson. One male, Chipola Lake, Gulf Co., April 6. Described by Mr. E. B. Williamson (1922, Ent. News, 33:114) as a new species from Gotha and Enterprise, Florida. It has not been recorded from elsewhere since its description. This record from Chipola Lake in Western Florida, greatly extends the range of the species.
6. **Enallagma laurenti** Calvert. Five males, three females, Bull Pond, Tallahassee, Leon Co., April 4. The female of this species has never been described. A description drawn from the above material follows:

The female is similar to the male as described by Dr. Philip P. Calvert (1919, Trans. Amer. Ent. Soc. 45:379) with the following modifications: The postclypeus (nasus) is in one specimen black with the margins and a median spot of yellow, (Fig. 2). The postocular spots are less broadly joined to the pale of the rear of the head than in the male as indicated by Dr. Calvert's figures, but more broadly than in most of the Florida males in the present collection, (Fig. 2). The prothorax is predominantly black in two of the three specimens, the pale lateral and median spots of the middle lobe being quite reduced. Dorsum of abdominal segments 1–8 black. Segment 9 with a triangular basal black spot on the dorsum, the apex of the triangle not reaching the apical margin of the segment. Segment 10 entirely pale. The usual ventral spine on the apical margin of abdominal segment 8. Total length, 36 mm.; abdomen, 30 mm.; forewing expanse, 42 mm.; length of hind wing, 20.5 mm.

In Mr. E. B. Williamsons key to the female of the Pollutum Group (1922. Ent. News 33:139), the female of *E. laurenti* would run out to *E. vesperum*, from which it is separated by the postocular spots broadly joining with the pale of the rear of the head.

One of the three females has an ant attached to the femur of the first pair of legs. Mr. Fredrick M. Gaige, of the University of Michigan, identified the ant as *Darymyrmex pyramicus*. A similar case was reported by Mr. E. B. Williamson (1922. Ent. News 33:143). This material is located in the Cornell University collection.

7. **Enallagma geminatum** Kellicott. One male, Bull Pond, Tallahassee, Leon Co., April 12. One male, two females, Sweet Water Creek, Liberty Co., April 3.
8. **Enallagma divagans** Selys. Twelve males, Chipola Lake, Gulf Co., April 6.
9. **Enallagma traviatum** Selys. Six males, Bull Pond, Tallahassee, Leon Co., April 12.
10. **Enallagma pallidum** Root. Five males, two females, two nymphs, one reared male with exuvia, Chipola Lake, Gulf County, April 6. A new Florida record and a new life history.

Enallagma pallidum was described by Dr. F. M. Root (1923. Ent. News 34:200) as a new species of Enallagma from Salisbury, Maryland. This species was placed in the Genus Enallagma and not Telagrion, by Dr. Root because of its small size (types, abdomen 26, hind wings 17 mm.). However, Dr. Root states, "At first sight, the slender form and the pale blue color of the specimens reminded me of *Telagrion daeckii*. . . . . When I came actually to compare the two, however, the smaller size and the shape of the male abdominal appendages showed at once that they were distinct. . . . . Dr. Calvert informed me that it was a new species of Enallagma most closely related appearently to *E. traviatum*." The finding of this species in Florida was a suprise, and an examination of the material has revealed the very interesting fact that *pallidum* is an intermediate between the Genus Enallagma and the Genus Telagrion, particularly the North American *Telagrion? daeckii* Calvert. The evidence follows:

(a) *Enallagma pallidum* is closely related to the Genus Telagrion (including *T. daeckii* and the Brazilian species *T. longum*) by certain characters of wing venation. The wings of Enallagma are never petioled to the anal cross vein. Those of Telagrion have one or both pairs petioled to, or nearly to, the anal cross vein. The Florida specimens of *pallidum* have both pairs petioled to the anal cross vein. In Telagrion M_3 and Rs are nearly parallel at their point of divergence from M_1, (Fig. 7). In Enallagma M_3 arises further proximad of Rs on M_1, making the enclosed area nearly triangular, (Fig. 9). *Pallidum* agrees with *Telagrion daeckii* in this character, (Fig. 8).

(b) *Enallagma pallidum* resembles *Telagrion daeckii* in coloration more than any other North American Enallagma. The head and prothorax of *Telagrion daeckii* are predominantly pale, the black being restricted to isolated spots and streaks, (Fig. 4). The palest species of Enallagma known to me is *E. laurenti*, where the black area of the head about equals the pale, (Fig. 2). In all other species of Enallagma the black covers by far the greatest part of the head and prothorax, (Fig. 1). *Pallidum*, while having more black than *daeckii*, is very much paler than *laurenti*, (Fig. 2). A similar reduction of coloration is to be found on the thorax of *pallidum* and *daeckii* and not in other species of Enallagma.

The femora of Telagrion are pale, with one or more ante-apical black rings, those of *pallidum* are also pale, with six or more dark rings, those of Enallagma are pale, with the black in longitudinal streaks.

Daeckii, *pallidum* and *E. semicirculare* are the only species of this group having abdominal segments 8–10 entirely pale in the male.

(c) *Enallagma pallidum* resembles *Enallagma antennatum* and *Enallagma traviatum* in the form of the male superior abdominal appendages. *Telagrion daeckii*, on the other hand, has little resemblance to these species (especially *E. antennatum*), in the form of the appendages. However, the appendages of *daeckii* are not un-Enallagma-like, resembling those of *E. praevarum* and *E. culicinorum*, but being quite distinct from either.

(d) In the matter of size, *pallidum* forms an intermediate between *Telagrion daeckii* and Enallagma proper. The type material of *pallidum* measured: Abdomen, 26 mm.; hind wings, 17 mm.; the Florida material, Abdomen, 30 mm.; hind wings, 20 mm. The larger species of Enallagma, *E. durum*, *laurenti*, etc., are recorded with measurements as high as abdomen, 32 mm.; hind wings, 24.5 mm.; the average for Enallagma being about, abdomen, 24 mm.; hind wings, 18 mm. *Telagrion daeckii* measures, abdomen, 36 mm.; hind wings, 24 mm.

(e) *Nymph.*—The immature stage of *pallidum* has never been described. A description of the Florida reared material follows:

Male.—Length, 14 mm.; length of gills, 7 mm.; length of abdomen, 8.5 mm.; length of metathoracic wing case, 4 mm. Head about one-half as long as wide, the caudo-lateral angles produced into tubercle-like processes behind the eyes, and setose. Antennæ six-jointed, second segment shorter than the first, third longer than the second. Labium when folded, reaching just beyond the prothoracic suture, not to the mesocoxa. Lateral setæ, 4; mental, 2. End hook of the lateral lobe followed by a series of 4 median sized teeth. Lateral margins of the median lobe with 6 setæ on a side. Femora without heavy setæ and with a well developed black preapical ring. Metathoracic wing cases extending to the middle of abdominal segment 4. Abdomen with the lateral keels poorly developed on segments 1–3, strongly produced behind on 4–7, lacking on 8–10. No heavy setæ on any of the lateral keels, a few whitish hairs on 4–7. Gills long and slender. The smaller tracheæ are collected in small dark algæ-like patches. The gill is also secondarily pigmented, the base, for about two-thirds the length of the gill and the extreme tip being dark, leaving a light cross band on the apical third. Like the gills of *E. antennatum*, which nymph this one resembles very closely.

Of the thirty-eight species of North American Enallagma, only eighteen of the nymphs are known, and only fourteen have been adequately described. Dr. James G. Needham described the nymph of *Telagrion daeckii* (1904, Proc. U. S. N. M. 27:715), the material for which I have at hand.

The known nymphs of Enallagma sharply divide into two groups based on the development of the lateral keels of the abdomen, and the presence or absence of heavy setæ on these structures. The following partial table of the nymphs and their characters will demonstrate the peculiar relationship of the North American Telagrion-Enallagma group as represented in the immature forms.

TABLE I. *

Species	Length	Gills	Length of Gills	Lateral Keels	Lateral Setæ	Ment. Setæ	Ring Fem.
E. pallidum.......	14	Pigmented in dark basal and apical bands.	7	Poorly developed, with no setæ.	4	3	well
E. antennatum	13–14	Subapical clear stripe.	7–8	Poorly developed, no setæ.	4–5	3	well
E. signatum	16–18	Pigmented in 3 cross bands and trachea.	5.5	Well developed, heavy setæ in clumps.	5	3	well
E. carunculatum	14	No pigment except in trachea.	5 5	Well developed setæ in rows.	6	3	poor
T. daeckii	18	No pigment except in trachea.	5 5	Well developed setæ in rows.	6	3	poor

It will be seen from the above table that *E.antennatum* and *E. pallidum* are in a group by themselves, separated from the other species in the table and those not in the table, by the pigmentation of the gills and the poor development of the lateral keels. It is also apparent that the nymph of *T. daeckii* is as closely related to the other group of Enallagma, as *pallidum* is to the *antennatum* division.

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*In this table column 2 is the total length in mm.; 4, the length of the gills in mm.; 6, the number of lateral setæ; 7, the number of mental setæ; 8, refers to the preapical dark ring on the femora. For photographs of the gills, see Dr. R. H. Howe, Manual of the Odonata of New England, Part I, Nymphs.

Conclusions. It becomes apparent, on consideration of the foregoing mass of material, that *pallidum* bridges well the gap between the North American Enallagma and Telagrion, and indirectly, through *daeckii*, with the South American Telagrion. *The only* character left solely to *Telagrion daeckii*, at least, that is its extreme length of 42 mm. *is not shared by an Enallagma, encroach upon this. The nymphal* and the larger *Enallagma* evidence makes it impossible to consider *pallidum* a Telagrion, *or to create a new genus for daeckii** and *pallidum*, either of *which one would be inclined to do on the strength of the adult material alone.*

The only other solution possible is to make daeckii an Enallagma.. When Dr. Calvert described *daeckii (1903. Ent.* News. 14:36) he placed it in the South American genus Telagrion questionably, with the remark that it was closer to Enallagma than to any other North American genus. So, perhaps, in the present light of *daeckii's* close connection to Enallagma, directly through the nymph, and by way of *pallidum* through the adult, it is wise to simplify the matter by making "*Telagrion? daeckii* Calvert" read "*Enallagma daeckii* (Calvert)," and so eliminate the name Telagrion from our North American fauna list.

Certainly the genus Enallagma is growing large and cumbersome, including, as it does, such diverse groups as represented by *cyathigerum, boreale, civile, antennatum, coecum, pollutum, semicirculare, cultullatum* (for which Dr. C. H. Kennedy created a new genus) and *pallidum.* The addition of *daeckii* will represent development in another direction. The situation is comparable in North American Odonatology, only with that other huge genus, Gomphus, with its manifold directions of development as represented by the four "subgenera," Stylurus, Ariogomphus, Gomphurus and Gomphus.

11. **Enallagma daeckii** (Calvert). One male, "Cyrilla Pond," southwest of Tallahassee, Leon Co., April 13.

12. **Enallagma concisum, vesperum, doubledayi, durum, cardenium, civile** and **cyathigerum** are known to occur in Florida, but were not represented in the present collection.

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*Dr. C. H. Kennedy (1920, Ohio Journ. of Sci., Vol. 21:87) makes *Telagrion daeckii* the type of a new genus which he calls *Teleallagma.* Stating, "Characters as in *Enallagma,* but the pair of subdorsal apical points of segment 10 are widened laterally into minute lobes, abdomen very slender. Wing petioles to Ac."

SOME NORTH AND SOUTH AMERICAN BEES.

By T. D. A. Cockerell,
University of Colorado.

There are signs that interest in wild bees is spreading in this country, particularly in the west. I hear of activities in Utah, Wyoming and Montana, all promising important results. The works of P. H. Timberlake and C. L. Fox, of California, will, when published, throw a flood of light on the genera *Perdita* and *Nomada* respectively. Dr. Kennedy writes me of collections in Ohio, and Messrs. Crawford and Mitchell are busy in North Carolina. Miss Sandhouse, at the National Museum, has begun to revise the whole series of Halictinae. Frison will give us an entirely new treatment of our Bombidae. The bees have been too much neglected. They share with the birds and butterflies the advantage of being readily seen, so that it is not difficult to make a fairly exhaustive collection in a locality. They are interesting and attractive, and their habits, parasites, etc., afford abundant materials for biological studies. The genera are not very numerous, and are easily learned. The species, however, are very many, and often extremely "critical." No one can name bees (unless perhaps *Bombus*) by just looking at them. The labor of sorting out the great masses of specimens accumulating in museums is too great for the workers now available, and hastily made determinations are often unreliable.

We need a monographic treatment of our bees, on the lines of the volume by Bingham in the "Fauna of British India," or of "Die Bienen Europa's," by Friese. I wish that such a work might be undertaken, with a suitable subsidy, as a memorial to Cresson, whose labors would necessarily be cited on almost every page. It would appear in parts, as ready, and when done would make it possible for entomologists all over the country to collect and study bees, determining what they found, instead of having to depend on others for critical work. As a preparatory step, it would be useful to issue a check list, with the names and localities only.

The difficulty of securing funds for printing is the most serious obstacle. When we publish taxonomic work it has to be abbreviated as much as possible, and thus made uninteresting.

It would be much better if descriptions of new species were accompanied by comments on the nature of the country they inhabit, the fauna they belong to, the distribution of the related forms, and so forth, but all this would take too much space as matters are now arranged. I have in preparation a check list of the bees of the world, which might well be thrown into the form of a study in geographical distribution, and would then have some general biological interest. It also shows which species are represented in several of the leading museums. Whether this can ever be printed, I do not know. I should not like to offer it to one of the journals knowing that if accepted it would crowd out more strictly original and therefore important matter.

Hypanthidium flavomarginatum (Smith).

Male. Jurujuba, Brazil, January 6, 1920. (*E. G. Holt*).

Megachile jurujubensis sp. n.

Female.—Length about 14 mm.; broad, robust, black, including the whole of mandibles and the tarsi; tegulæ dark chestnut red, finely punctured, wings rather dilute fuliginous; mandibles with a very broad cutting edge, with a pair of teeth at apical end, and inner corner produced; clypeus convex, shining, well punctured, but sparsely so in middle; lower edge briefly and obtusely bilobed in middle, with a pit-like median depression; supraclypeal area strongly punctured; antennæ black, the flagellum obscurely reddish beneath; vertex and front with black hair, face with mixed black and white, the white especially about antennæ and at sides of lower part of face; cheeks with dull white hair; mesothorax and scutellum dull, excessively densely and minutely punctured, mesopleura also dull; thorax above with dull white hair, mixed with black, mostly short and black on disc of mesothorax; upper part of mesopleura with long black hair, tubercles broadly fringed with white; tarsi thick, the small joints produced on each side; hind basitarsi long, broad and flat, about or nearly as long as the tibiæ; spurs whitish; hair of legs partly black, partly pale; middle tarsi with a short fringe of white hair behind; abdomen broad and short, weakly punctured, first segment covered with dull white hair, the others only with inconspicuous black hair, except that at base of third segment laterally there are indications of a white band; ventral scopa white, broadly black at sides of third and fourth segments, and black on segments beyond.

Jurujuba, State of Rio de Janeiro, Brazil, January 6, 1920, (*E. G. Holt*). Given to me by Mr. L. O. Jackson. In Schrottky's table it runs next to *M. pocograndensis* Schrottky, but that has the thorax and base of abdomen yellowish-haired, and dark tegulæ. It is not very close to any species known to me.

Megachile hoffmannseggiae Jorgensen.

Females. La Rioja, Argentine. (*Giacomelli*).

Megachile hoffmannseggiae hypoleuca var. n.

Female.—Length about 11.5 mm.; differs by hair of sides and venter of thorax entirely dull white, instead of black; legs with pale hair. Hair of front white, mixed with black; hair of thorax white, not yellowish; sparse black hairs on discs of mesothorax and scutellum; wings dusky; abdomen with white hair bands; ventral scopa bright red.

La Rioja, Argentine (*Giacoxelli*). Possibly a distinct species, but I think not. *M. pamperella* Vachal appears to be an analogous variety of *M. infima* Vachal. I hesitated whether to refer this to *M. steinbachi*, but Friese describes that species as having yellowish hair, and the abdomen densely punctured. Also, there is apparently no white hair-band in scutello-mesothoracic suture, this being very distinct in *hypoleuca*.

Melissodes lavata Cockerell.*

Male.—Length about 13 mm., anterior wing 10.3 mm.; black, robust, the head and thorax with long white hair, wholly without black or fulvous; eyes pale green; head very broad, facial quadrangle broader than long; apical part of mandibles obscurely reddish; labrum with pale yellowish hair; clypeus densely rugose punctate; flagellum beyond the second joint chestnut red beneath; sides of front above deeply concave and shining; mesothorax and scutellum shining, with scattered strong punctures; tegulæ dark reddish, with light hair; wings brownish hyaline, nervures and stigma dusky ferruginous; basal nervures falling short of nervulus; third submarginal cell longer below than first; legs with mainly pale hair, the copious scopa on outer side of hind legs cream-colored and strongly plumose; hair on inner side of hind basitarsus rusty black; hair on inner side of anterior and middle basitarsi ferruginous; abdomen with pure white hair–bands on segments 2 to 4, on 2 and 3 rather narrow, on 4 broad and entire; hind margin of first segment broadly and suffusedly reddish; hind margins of segments 2 and 3 broadly red-brown; concealed parts of segments covered with chocolate-covered tomentum; fifth and sixth segments with dark chocolate hair, some pale at extreme sides of fifth.

Wray, Colo. 1 ♀. (*Lutz* 4412C), August 17–19, 1919. Differs from *M. glenwoodensis* Ckll. by the broader face, hair on outer side of middle tarsi light, brown tomentum covering concealed parts of abdominal segments. In my key (Tr. An. Ent. Soc. XXXII, p. 86) it runs to the vicinity of *M. blakei* and

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*This species was very briefly described in a footnote in *Pan-Pacific Entomologist*, Vol. I, page 56.

M. mizeæ. The following key separates it from these and others:

Hair-band of third abdominal segment very broad, occupying most of segment; hair of thorax above pale fulvous; large robust species.........**mizeæ** Ckll.
Hair-band of third abdominal segment relatively narrow, not broader than the bare marginal area behind it... 1.
1. Hair of thorax above pale fulvous or yellowish................................ 2.
Hair of thorax above white.. 3.
2. Tegulae bright ferruginous; wings strongly brown; bands on abdominal segments 3 and 4 pure white..................................**hitei** Ckll.
Tegulae rufopiceous; wings clearer; bands on segments 3 and 4 tinged with yellowish...**blakei** Ckll.
3. Middle tarsi with black hair, their tibiae with red hair on outer side, **glenwoodensis** Ckll.
Middle tibiae and tarsi with pale (slightly brownish) hair on outer side, **lavata** Ckll.

(In Robertson's table (Tr. Am. Ent. Soc. XXXI, p. 369) **M. lavata** runs out at 16.)

Halictus perater sp. n.

Male.—(Type). Length about 5 mm., the apical abdominal segments retracted; black, with the head dark steel blue; pubescence scanty; no light markings on head or legs; tarsi long, brownish apically; face broad, inner orbits concave, but not emarginate; clypeus not produced; face shining, front dull; antennæ with very long moniliform entirely dark flagellum; mesothorax and scutellum dull black, slightly shining, finely punctured; area of metathorax more shining, large, rounded behind, with a broad obtuse margin which does not extend to sides, basally with fine plicæ; posterior truncation with a median sulcus, sides not sharply defined; tegulæ shining, very dark brown, sparsely very minutely punctured; eyes without hair; wings brownish hyaline; stigma dark red-brown, nervures fuscous, outer nervures not distinctly weakened; second cubital cell produced at lower basal corner, receiving recurrent nervure just before end; legs shining; hind tarsi very long; abdomen highly polished, impunctate, without hair bands or spots.

Female.—Similar, except for the sexual characters. Head blue-black; antennæ short, flagellum not pale beneath; plications at base of metathoracic enclosure feeble; hind spur with three strong oblique teeth.

Huascaray, Peru, 6,500 ft., September 21 (*C. H. T. Townsend*). Very similar to *H. semiviridis* Friese, from Bermuda, but the male of *H. perater* has the face much broader and the mesothorax much duller, while the female has a narrower, intense black abdomen. It cannot properly be referred to *Chloralictus*, nor does it fit well in any known subgenus.

Andrena albihirta (Ashmead).

A female from Boulder, Colorado, May 6, 1922 (*Maxy Pope*), carries two *Stylops*.

Andrena (Trachandrena) eriogoni sp. n.

Female.—Length about 9 mm., anterior wing 8.3 mm.; black, including antennæ and mandibles, but small joints of tarsi dusky reddish, and tegulæ reddish brown, subtestaceous, dark in front; wings reddish hyaline, stigma and nervures dull ferruginous; malar space linear; process of labrum broadly truncate; clypeus shining, but closely and strongly punctured, with a smooth median ridge on lower part; facial foveæ creamy white, half as broad as distance between eye and antenna, rapidly narrowing below, ending a little below level of top of clypeus, only a smooth line between fovea and orbit; vertex densely punctured; third antennal joint long, fully as long as next two together; head with ochreous hair, conspicuous at top, at level of antennæ and on cheeks; mesothorax and scutellum with very coarse dense punctures, on posterior disc of mesothorax some shining space between the punctures; hair of thorax above dull ochreous, dense, short and coarse; area of metathorax dull, with about 14 strong parallel ridges; stigma large; basal nervure falling a little short of nervulus; second cubital cell narrow, receiving second recurrent nervure beyond middle; femora with ochreous hair, tibiæ with sooty, tarsi with black, but dark red on inner side of anterior tarsi; spurs light ferruginous; abdomen bare, not banded, apical hair brownish-black; second segment in middle depressed much more than one-half, but not quite two-thirds; elevated parts of segments extremely densely punctured; depressed parts shining, with very fine punctures; the hind margins of second and third segments reddened; ventral segments more or less reddened basally.

At flowers of *Eriogonum*, above Ute trail, Roan Mountains, Colorado, July, (*Cockerell*). Closely related to *A. crassihirta* Vier., and *A. perdensa* Vier., from the northwest, and separated by the combination of thick ochreous hair above and whitish foveæ, as well as the smaller size. The subgenus *Trachandrene* also occurs in Europe. A very handsome species is *A.* (*T.*) *albicans* (Muller), which I collected at Winfrith, Dorset, April 20.

Andrena topazana Cockerell.

Female. Roan Mountains, Colorado, above Ute trail, July (*W. P. Cockerell*).

Andrena lewisii Cockerell.

Female. Top of Roan Mountains, Colorado, above Ute trail, July (*W. P. Cockerell*). Compared with the type, it is larger and with darker nervures, but certainly this species.

Augochlora holti sp. n.

Male.—Length about 9.5 mm.; head and thorax bright emerald green, the disc of mesothorax suffused with golden; legs with green femora; hind coxæ and trochanters entirely green; tibiæ black, the anterior ones dull honey color in front; anterior tarsi honey color, the others dark fuscous; abdomen shining brilliant green, with slight golden tints on disc of first two segments, hind margins of segments black, on segments 3 to 5 there is a strong blue suffusion before the black bands; venter black, simple, the hind margins of the segments obscurely brown, the third segment with the hind margin obtusely rounded in middle; tegulæ ferruginous; wings dusky hyaline; stigma dusky reddish, nervures fuscous; second cubital cell high and narrow; first recurrent nervure reaching basal corner of third cubital cell (as in *A. feronia* Sm.). Clypeus much produced, shining, strongly and not very densely punctured, its apical margin narrowly dark brown; labrum brown; mandibles ferruginous, with a green spot at base; antennæ not very long, black, the flagellum obscurely brown beneath; eyes strongly emarginate; front very densely punctured; mesothorax shining, strongly and quite densely punctured; scutellum sparsely punctured on disc; metathorax rounded, closely punctured, the basal area short, semilunar, regularly striated, and with a well-defined rim; abdomen with short white glistening tomentum; legs with white hair.

Jurujuba, State of Rio de Janeiro, Brazil, January 6, 1920 (*E. G. Holt*). Given to me by Mr. L. O. Jackson. This cannot well be the male of *A. feronia* Sm., as that has black femora, and the abdomen black at base; yet it is evidently allied. *A. daphnis* Sm. (male) differs conspicuously in the yellow margin of clypeus and lower side of flagellum. *A. metallica* Fab. (male) is more slender, much bluer, with much narrower face. *A. azteca* Vach. (male) is also much narrower and bluer, with much more closely and coarsely punctured first abdominal segment. *A. graminea* Fab. (from F. Smith's collection) has an entirely different metathorax. *A. caerulior* Ckll. is also easily separated by the metathorax. In Vachal's table it runs to the vicinity of the quite different *A. muelleri* Ckll. and *A. rohdei* Vach., the latter being only 6.5 mm. long.

Augochlora (Augochloropsis) **viridilustrans** sp. n.

Female.—Length about 8.5 mm.; brilliant emerald green, without any blue or purple tints (the type of *A. artemisia* has the abdomen bluish green, with purple tints, and strong purple tints on vertex); face very broad, orbits almost parallel; emargination of eyes broad, not abrupt; hair of head and thorax not very abundant, yellowish dorsally, dull white below; process of labrum binodose; mandibles black with a bright ferruginous spot in middle; clypeus convex, well punctured, the lower margin broadly black; clypeus and sides of face flushed with golden; front dull, but sides of face glistening; flagellum very obscurely reddish beneath; mesothorax and scutellum dully, excessively minutely and densely punctured; tubercles obtuse; area of metathorax semilunar, covered with fine radiating striæ, posteriorly in the middle with an obtuse thickened rim; posterior truncation well defined, granular, not polished; wings dusky hyaline; stigma and nervures dull pale yellowish brown; second cubital cell large, square, receiving first recurrent nervure at its end; coxæ, trochanters, femora and tibiæ green, including both sides of hind tibiæ; tarsi black, the front ones reddened apically and the hind ones more or less reddish; hair of legs more or less pale orange tinted, especially on inner side of tarsi; hind spurs with four long spines; abdomen broad, shining green, with weak piliferous punctures; first segment not or hardly at all vibrissate, but second extremely briefly vibrissate, the hairs white; segments 2 to 4 with thin apical bands of white hair, only clearly evident in lateral view, the last two broad; beyond the fourth segment the abdomen is black above and below; venter mainly green as far as fourth segment.

Jurujuba, Brazil, January 6, 1920 (*E. G. Holt*). Given to me by Mr. L. O. Jackson. Very close to *A. electra* Sm. (*Artemisia* Sm.), but easily separated by the area of metathorax, which in *A. electra* is smooth and shining. According to Schrottky, *A. cubiceps* Vachal is the same as *A. electra*. In Trans. Amer. Ent. Soc. (1905, p. 361), I gave differential characters, based on a *cubiceps* from Vachal compared with Smith's type of *artemisia*. Vachal recorded *cubiceps* from Montevideo, Brazil and Mexico, and I have little doubt his series was composite, the Brazilian material probably being *electra*. In Schrottky's table of Brazilian species, *A. viridilustrans* runs straight to *A. monochroa* Ckll., which is very different by the area of metathorax and long vibrissæ.

Exomalopsis (Anthophoru) torticornis sp. n.

Male.—Length about 6 mm., anterior wing about 4 mm.; black with the clypeus, labrum and basal half of mandibles light lemon yellow; apical half of mandibles dark red; eyes pale greyish green; ocelli large; facial quadrangle long and narrow; head and thorax with abundant white hair; on thorax dorsally are two broad bands of reddish hair, not very conspicuous, meeting on scutellum; scape long, curved, black; flagellum bright ferruginous, dusky above and black at tip; third antennal joint strongly bulging below, so that the base of the flagellum appears twisted or distorted; mesothorax shining, finely punctured; tegulæ pale reddish; wings very short, hyaline, apical margin broadly dusky, stigma and nervures black; three cubital cells, the second small, receiving the recurrent nervure near its apex; legs black, with much white hair, tarsi and spurs pale ferruginous; abdomen rather narrow, elongated, tapering, curved downward, shining, very finely punctured, the segments with very broad even bands of white tomentum, the first segment hairy all over, with a transverse pale brownish band; venter reddish.

Los Angeles, California, June 22, 1926 (*Chas. H. Hicks*). A remarkable little species, nearest to *E. chlorina* Ckll., from New Mexico, which is only known in the female. It cannot well be the male of *E. chlorina*, as that species has the stigma and nervures pale ferruginous, and a very much larger and broader second cubital cell.

Exomalopsis giacomellii sp. n.

Female.—(Type). Length 6–6.5 mm.; short and robust, black; lower edge of the shining almost impunctate clypeus, labrum, broad base of mandibles and flagellum beneath, ferruginous; clypeus depressed in middle, obtusely ridged on each side of disc; eyes pale green; head and thorax with white hair, the mesothorax posteriorly and scutellum anteriorly bare, polished, impunctate; tegulæ translucent testaceous; wings hyaline, slightly milky, stigma and nervures testaceous; second cubital cell small, in one specimen the second intercubitus is entirely lacking on one side; femora shining black, tibiæ and tarsi rufous, anterior tibiæ blackish on outer side; hair of legs pale, scopa of hind legs entirely dull white, except for a hardly noticeable brownish stain above; abdominal segments with the hind margins testaceous; first segment highly polished, with a conspicuous transverse band of white hair across middle, sometimes denuded; remaining segments (unless denuded) entirely covered with appressed dull white hair; hair at apex stained with reddish; venter black, slightly stained with red.

Male.—The only specimen is in poor condition; it differs by the much narrower abdomen, with hind margins of second and third segments conspicuously red; longer antennæ; hind femora rather broadly red at apex. The clypeus is black.

La Rioja, Argentina, 4 ♀, 1 ♂ (*Giacomelli*). Resembles *E. pilosa* Sm., from Brazil, but differs by the second abdominal segment being clothed like the following ones. There is also some resemblance to *E. solitaria* Brethes, the exact locality of which is unknown, though it is probably from Argentina. About 43 apparently valid species of *Exomalopsis* are known from South America. This is the ninth from Argentina. Southward they become scarce; only one species (*E. jenseni* Friese) was found at Mendoza, but I have described one from Patagonia.

Diadasia diminuta (Cresson).

Male in squash flowers, Grand Junction, Colorado, August 20, 1926 (*Mary Jaquette*).

Hylaeus basalis (Smith).

Male. Near Beaver Lake, Colorado, at flowers of *Entoca sericea*, June 23 (*W. P. Cockerell*).

A CONTRIBUTION TO THE BIOLOGY AND DISTRIBUTION OF ONE OF THE LEGIONARY ANTS, ECITON SCHMITTI EMERY.*

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This ant is of special interest because it is one of the few species of *Eciton* or legionary ants known to occur in the southern and central sections of the United States. The legionary or driver ants are most common to the tropics where they attract considerable attention on account of their remarkable foraging raids in which many arthropods and small vertebrates are killed and directly eaten by the ants.

In this country very little is known about *E. schmitti* Emery or any of the related species since the ants are mostly subterranean in habit and seldom seen. In view of this fact the writer thought that he might add to the knowledge of the feeding habits of this species by recording some observations which he has made during the past fall (1926). It was also thought worth while to briefly summarize here our present knowledge of the distribution and biological habits of this species.

Eciton schmitti Emery is at present known to be distributed in the United States from Texas and New Mexico eastward to North Carolina and from the Gulf States northward to Colorado and Iowa. It has been definitely recorded from the following states: Texas, New Mexico, Colorado, Missouri, North Carolina, Kansas, Louisiana, Mississippi and Iowa. The writer believes that careful collecting will reveal its presence in a number of other states, most of which lie within the range just mentioned.

This ant, like the other species of *Eciton*, does not appear to live long in any one nest but moves like a nomad from place to place occupying only temporary habitations. These moves are probably governed largely by the availability of food for them. Their nests occasionally have been found in the soil beneath stones and concrete sidewalks and the steps of houses. The colonies, judging from what the writer has seen of them, are moderately large in size. Unlike many ants, this species has

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*A contribution from the Mississippi Agricultural Experiment Station).

only one female to a colony, this female being of huge size when compared to the workers. In this respect the female of *E. schmitti* Emery bears a similarity to that of a large termite queen. The female is from 13–17 mm. in length, is never winged and because of her large size and apterous condition is known as a dicthadiigyne. The males are also large and striking in appearance and resemble wasps more than they do ants. One of the peculiarities of this sex is the fact that the males, like the females, possess a single segmented petiole whereas the workers have a two segmented petiole. The workers are polymorphic, highly chitinized insects with exceedingly small eyes, which appear on the sides of their heads like small ocelli. Due to their vestigial eyes the workers depend on their sense of odor for a guide in traveling and for this reason they always follow a very definite trail.

Wheeler has taken alate males of this species in Texas on October 3rd and 13th and the writer has received specimens from Mr. O. W. Rosewall at Baton Rouge, Louisiana, which were captured there on the 16th of November. It would appear from these records that the males do not reach maturity until late in the season.

No one seems to have made any observations on the number of females produced by a colony or the time of year that they reach maturity. The females are so secretive in disposition that very few have been observed. The writer does not know of over three females in existence in the collections of this country, a fact which indicates their rarity.

According to Wheeler the odor of the workers is very disagreeable, similar to that of fecal matter and he attributes this to the fact that the ants feed entirely on flesh. The males and females have a pleasant odor and the workers seem to enjoy clustering around them. Wheeler says that he does not know of any ants in which the workers show such an extreme fondness for the sexed forms as do the workers of these ants. A colony which he kept in captivity was most active between five and seven oclock in the evening, after this time their activity seemed to die down.

In Texas, Wheeler found that this ant robbed and fed upon the brood of other ants. He succeeded in identifying some of the appropriated brood and found that it belonged to the fire ant, *Solenopsis geminata* Fabr. and to several species of *Pheidole.*

He also noted that the ants fed on carabid beetles belonging to the genera *Harpalus* and *Pterostichus* and a species of undetermined termite.

During the past fall (1926), the writer encountered these ants on three occasions; each time they were engaged in raiding the nests of other ants. They were first encountered at McComb, Mississippi, on the forenoon of October 11th at which time the ants were observed carrying in their mandibles females and workers of the Argentine ant, *Iridomyrmex humilis* Mayr, workers of the ants, *Camponotus caryæ* subsp. *rasilis* Wheeler and workers of an undetermined species of termite. No larvæ of any of these forms were seen in the mandibles of the ants, but these may have escaped observation. All of the prey was secured from the base and trunk of a large oak tree. At Columbus, Mississippi, the ants were encountered a second time in the late afternoon of November 4th. At this time the ants were noted to be carrying workers of the following species: the small sugar ant, *Prenolepis* (*Nylanderia*) sp., the tiny thief ant, *Solenopsis molesta* Say and those of an undetermined species of termite. The prey was apparently secured from cavities in the soil beneath a pile of leaves. On the afternoon of November 13th the ants were observed for a third time at Mayhew, Mississippi. They were noted to be carrying termite workers and soldiers of the ant, *Pheidole vinelandica* Mayr. Some were seen carrying to their nest several carabid beetles, species undetermined. One of these beetles was decapitated and appeared to have been freshly killed. The nest of the ants was found in a slightly open grassy spot about eight feet from the base of a fence post from which they were getting the termite workers. The nest was so inconspicuous that the writer would never have discovered it had he not seen the worker ants returning to it with their prey Although the workers of *E. schmitti* Emery were not observed to directly eat the species which they captured it is not presuming too much to assume that they did, as all species of the genus, so far as the writer is aware, are entirely carnivorous and there is every reason for supposing that they would eat ants as quickly as other insects. Wheeler has observed them feeding on the brood of other ants and this is in line with the assumption that they also feed on adult ants as well. Several years ago the writer received a note from Mr. Andrew Fleming of Sibley, Mississippi stating that he had found the workers of *Eciton pilosus* F. Smith carrying workers of a species of ant in their mouths. The ants which the workers were carrying were sent to the writer for determination and he found them to be those of *Creamatogaster ashmeadi* Mayr an ant, which in this section nests in trees, plants, etc., never in the soil. All of the observations mentioned here seem to prove that the species of *Eciton* in this section at least, often feed on the adult ants as well as the brood.

ON THE BIOLOGY OF SOME ICHNEUMONIDS OF THE GENUS PANISCUS SCHRK.

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INTRODUCTION.

The Ichneumonids of the Genus *Paniscus* belong to a small but well-differentiated group, the mumbers of which superficially resemble the species of the Genus *Ophion* from which, however, they differ markedly in structure. They are supposed to be parasitic primarily upon lepidopterous larvæ.

The information available concerning the biology of the members of the Tribe Paniscini relates mostly to the species of the Genus *Paniscus*. As early as 1700 Goedart (1) reared five specimens of *Paniscus cephalotes* Hlgr. from the caterpillar of the puss moth (*Diacranura vinula* L.) and figured the bundle of cocoons from which these specimens emerged. Bonnet (2) in 1755 published in brief some observations on the egg and larval growth of *Paniscus*, and in 1771 DeGeer (3) gave a short account of the biology of a parasite belonging probaly to this genus. The life history of *Parabatus virgatus* Fourcr. was described in 1852 by Newport (4) and that of *Paniscus cephalotes* Hlgr. in 1886 by Poulton (5). Chewyreuv (6) published an important contribution in 1912 on the biology of *Paniscus cristatus* Thoms. and *Paniscus ocellaris* Thoms., both parasites of *Agrotis segetum* Schiff. Cushman (7) made some notes on the life history and morphology of *Paniscus geminatus* Say in 1913, while Strickland (8), in his paper on the parasites of prairie cutworms in 1923, gave a partial account of an undetermined species belonging to this group found by him attacking the larvæ of *Porosagrotis orthogonia* Morr. A systematic revision of the American Paniscini was published by Cushman (9) in 1924, and a review of the life and habits of the Genus *Paniscus* was given by the same author (10) in 1926.

The observations recorded in this paper,* on *Paniscus spinipes* Cushman and *P. geminatus* Say var. *sayi* Cushman

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*The writer wishes to thank Dr. L. O. Howard for supplying a translation of Chewyreuv's study on *Paniscus*; R. A. Cushman for his determination of specimens, and Dr. W. J. Phillips and Dr. W. R. Thompson for their helpful suggestions in the preparation of this manuscript.

(Fig. 1), were carried on at the United States Entomological Laboratory, Charlottesville, Virginia, in the late summer and autumn of 1924. During this year about five per cent of the larvæ of the corn earworm (*Heliothis obsoleta* Fab.) collected in certain localities were attacked by these parasites.

HANDLING AND REARING.

The type of cage (Fig. 2) which the writer found most satisfactory for experiments on *Paniscus* consisted of a glass cylinder twenty inches in height and ten inches in diameter. The cylinder was placed on end upon a table near a window, the top end was covered with a single layer of cheesecloth, and a white paper towel was placed on the bottom. In the cheesecloth cover there was an opening several inches square over which was fastened a piece of pasteboard, on the under side of which a hanging drop of thick honey was placed.

Each female parasite was confined in a separate cage. The material for these experiments included not only individuals reared in the laboratory, but also specimens that were collected in the field. Females from each source apparently reproduced with equal freedom in captivity.

Because of the cannibalistic habits of the corn earworm larvæ which served as hosts for the parasite, it was necessary to isolate each larva as much as possible. This was accomplished by standing a block of wood sixteen inches high and two inches square, upright in the center of the cage. At intervals around this "holder" were driven small spikes, upon each of which was impaled a section of corn ear that had just passed the milk stage of its growth. One large earworm larva was placed on each piece of corn ear. In this way the larvæ were somewhat separated from one another and at the same time they were fully exposed to the action of the parasite.

A watch glass filled with a seventeen per cent sugar solution was placed on top of the "holder." This solution and the hanging drop of thick honey were kept continually in the cage, and *Paniscus* was observed to feed on both, although the sugar solution seemed to be preferred.

Ordinary jelly glasses (Fig. 3) were filled with several inches of sterile soil, upon the surface of which was placed a single larva of *Heliothis absoleta* Fab. bearing eggs of *Paniscus*. These host larvæ were supplied with corn kernels, and those that were not fully matured fed a little before entering the soil to pupate. When the host larvæ enter the soil they carry the attached parasite eggs or larvæ with them. The pupal cell is made in the soil by the host caterpillar in the usual way, but the parasite larva soon destroys its host and constructs its cocoon in the larval cell.

After an interval of about three weeks the soil in each jelly glass was examined and the *Paniscus* cocoon found was removed and buried about an inch deep in soil in a glass vial (Fig. 3) in order that it might be more easily handled. Here it was allowed to remain until the adult insect emerged. The amount of moisture present within the vials did not seem to affect emergence.

The temperature of the laboratory during this work varied from a minimum of about sixty degrees Fahrenheit at night to an average of about seventy degrees during the day.

Under such conditions of confinement the life of four females was respectively seven, thirteen, thirty-four, and fifty-four days. The two females living seven and thirteen days respectively were mated individuals of *Paniscus spinipes*. The female that lived fifty-four days was unmated and the female that lived thirty-four days was probably unmated, also. These last two were specimens of *Paniscus geminatus* var. *sayi*.

COPULATION.

Coition was twice observed among specimens of *Paniscus spinipes*, the process being very similar in both instances. An observation made one day at ten o'clock in the morning may be described as follows:

A male and female being placed in a breeding cage, both flew at once to the under side of the cheesecloth cover, where the male, after following the female about for a few minutes, finally overtook her and climbed upon her back. As soon as the genital organs of the two insects had made perfect contact, the male relaxed all hold upon both the female and the cheesecloth cover and swung free in the air, head downwards, while the female still clung to the cover and thus supported both herself and the suspended male. The ovipositor was brought at right angles to the dorsal surface of the female and was, therefore, entirely out of the way of the male during the mating process. Copulation continued for five minutes in the attitude described, after which the insects separated and crawled independently about the cover.

It is interesting to note that in 1771 DeGeer (3) observed and made possibly the first record of the act of copulation among the Ichneumonids. Few such observations seem to have been recorded. In DeGeer's account it would appear that copulation occurred with both the male and female resting upon the upper side of a horizontal surface.

OVIPOSITION.

Females of *Paniscus spinipes* and *P. geminatus* var. *sayi* both readily oviposited upon larvæ of *Heliothis obsoleta* Fab. when kept in glass cages under laboratory conditions as previously described. Oviposition was observed a number of times and in each instance the host larva was stung before oviposition was attempted. The following typical observation was made one day at 8:30 P. M.:

After being rather active about the top of the cage for an hour, the female walked slowly down the side of the glass cylinder. When about eight inches from the bottom she flew to a section of corn ear on the "holder," upon the back of which was feeding a large earworm larva in its last instar. The parasite immediately sensed the presence of this larva, approached cautiously and quickly thrust her sting into it. Following the stinging she remained quitely on the piece of corn, facing her victim. In less than five seconds the host larva rolled from the corn to the bottom of the cage, where it lay motionless. Almost immediately the female was upon it, singling out this particular larva from among a half dozen others crawling about the bottom of the cage. Alighting upon it, with her head toward the caudal end of the caterpillar, the parasite arched her abdomen and began "brushing" about with her ovipositor along the three thoracic segments. Her ovipositor finally came to rest near the posterior margin of the second thoracic segment and was slightly inserted into the larva's body. In a few seconds an egg came sliding down the front exterior of the ovipositor and landed on the body of the larva. The ovipositor was then moved not more than one-sixteenth of an inch and a second egg was deposited on the same thoracic segment of the host.

Chewyreuv's (6) description of oviposition by *Paniscus cristatus* Thoms. is about as follows:

The female parasite turned her head towards the caudal end of the host larva and inserted her ovipositor about one-fourth of its length into the lateral part of the interspace between the prothorax and mesothorax. An egg issued through a cleft formed on the ventral side of the abdomen near the base of the ovipositor and slid down the outer, lower side of the ovipositor to the skin of the larva, where it became attached.

Frequently earworm larvæ were attacked while crawling about the bottom of the cage. Several instances were noted in which stinging and oviposition took place while the larvæ were wedged between kernels of corn upon which they were feeding.

The actions of one female of *Paniscus spinipes* were rather unusual and may well be recorded here. She flew to the bottom of the cage where a number of earworm larvæ were crawling about and successively stung four different larvæ. Each of the larvæ was completely paralyzed and a single egg was deposited upon the fourth larva, after which she fed a little at the puncture and then left without any further attention to the other paralyzed larvæ.

Immediately following oviposition, the female parasite sometimes feeds for a few seconds upon the body juices of the parasitized larva, either from a wound caused by the ovipositor or from a fresh incision made with her mouthparts. This method of feeding is only occasional and does not occur each time ovipositon takes place. This peculiar habit among the parasitic Hymenoptera was first recorded by Marchal (11) in the case of *Tetrastichus xanthomelaenæ* Rond., a parasite of *Galerucella luteola* Mull. It has since been mentioned by other authors, and during the course of his experiments Chewyreuv (6) observed a *Paniscus* female licking up some fluid from the back of a caterpillar.

All but a very small proportion of the eggs of the species here studied were deposited on one of the three thoracic segments of the host larva (Fig. 4). This agrees with Chewyreuv's observations (6). Chewyreuv, however, states that most of the eggs of *Paniscus* were placed between, rather than upon, the larval segments. The writer found upon careful examination that the eggs were always attached to some particular segment, although they were often very close to the margin and would almos tappear to be between the segments.

From one to five eggs may be deposited upon a single host larva, but apparently never more than one *Paniscus* larva survives; several may hatch but for some unknown reason all except one soon die. Poulton (5) recorded a similar observation in his study on *Paniscus.*

The two species of *Paniscus* studied by the writer may oviposit either during the day or night, although observations indicate that they favor nocturnal oviposition. According to Chewyreuv (6) the female of *P. cristatus* Thoms. deposits her eggs either in the daytime at twilight or in the evening, while the female of *P. ocellaris* Thoms. oviposits only in the evening.

Both *Paniscus spinipes* and *P. geminatus* var. *sayi* paralyze their hosts by the injection of some toxic substance before ovipositing upon them. Chewyreuv (6) observed this habit in *P. ocellaris* Thoms., but *P. cristatus* Thoms. deposits its eggs upon active, writhing larvæ without the formality of paralyzing them.

One female of *Paniscus geminatus* var. *sayi* deposited ninety-five eggs upon seventy-eight full-grown or nearly full-grown larvæ, most of which were *Heliothis obsoleta* Fab. On several occasions cutworm larvæ were placed in the cage with the earworms and the parasite chose the cutworm in preference to the earworm larvæ in each instance. One army worm was introduced into the cage and it also was chosen in preference to the earworm larvæ for oviposition. This female Paniscus lived for a period of 34 days; she began oviposition six days after she was placed inside the cage; then followed an egg-free period of five days; during the next twenty-three days she deposited an average of four eggs per day.

The number of eggs placed on a single larva varied from one to four. Of the seventy-eight parasitized larvæ previously mentioned, sixty-six or 84.61 per cent had one egg attached; eight or 10.26 per cent had two; three or 3.85 per cent had three; and one or 1.28 per cent had four eggs. The exact location of these eggs on the host larvæ is given in Table 1. It is an interesting fact that this particular parasite placed 80 per cent of her eggs on the anterior margin of the ventral surface of the first thoracic segment, just back of the head. Such a distribution of the eggs may prove to be characteristic of this species.

Three days after mating a female of *Paniscus spinipes* began oviposition and laid seven eggs per day for five consecutive days. These thirty-five eggs were placed on twenty-one different earworm larvæ, the number varying from one to five eggs per larva. Twelve larvæ bore only one egg each while two eggs were attached to each of six others. Two larvæ received three eggs each and one had a total of five eggs fastened to its body. Another female of the same species, after a pre-oviposition period of three days, deposited fifty eggs in ten consecutive days, or an average of five per day. These fifty eggs were placed on forty-five different larvæ. Forty of these bore only one egg each and the remaining five larvæ received two eggs each.

TABLE I.

Location of Eggs Deposited by *Paniscus geminatus* var. *sayi* (7P-83) on Larvæ of *Heliothis obsoleta* and others.*

Larval Segment	Position on Segment	Number of Eggs	Percentage of Total Oviposition
First thoracic	Anterior margin of ventral surface	76	80.00
	Anterior margin of dorsal surface	1	1.05
	Anterior margin of left lateral surface	1	1.05
	Posterior margin of left lateral surface	7	7.37
	Posterior margin of right lateral surface	3	3.16
	Total	88	92.63
Second thoracic	Anterior margin of left lateral surface	2	2.11
	Anterior margin of right lateral surface	1	1.05
	Posterior margin of right lateral surface	1	1.05
	Posterior margin of left lateral surface	1	1.05
	Middle margin of left lateral surface	1	1.05
	Middle margin of dorsal surface	1	1.05
	Total	7	7.36

The position of all of the eggs deposited by these two females was carefully noted, and while all of them were situated on the anterior part of the body, and the great majority on the three thoracic segments, there was no such restricted distribution as in the case of *Paniscus geminatus* var. *sayi.*

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*Cutworms and army worms.

Three unmated females of *P. geminatus* var. *sayi*, confined in glass cages without host larvæ upon which to oviposit, dropped eggs on the cage bottom that hatched normally. Larvæ hatched in this manner had no hosts upon which to feed and therefore could not be reared.

Chewyreuv (6) concludes his paper with the statement that the habit of dropping eggs promiscuously is common to a great Ichneumonids and that in the case of oviparous females it results from the accumulation of too many eggs in the oviduct. With viviparous females such action is due not only to an excessive number of eggs in the oviduct but also to the necessity of the female to get rid of her carnivorous young.

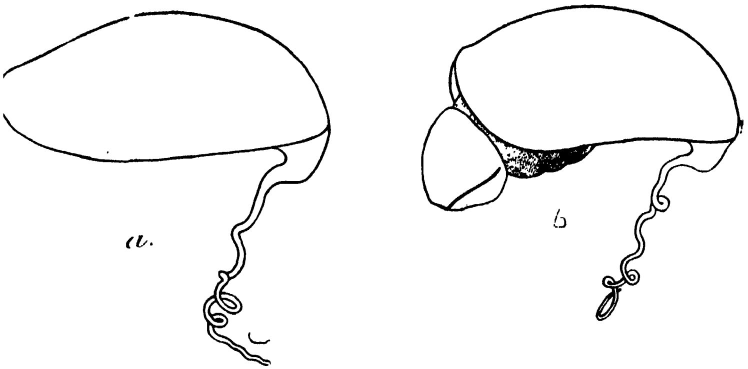

Fig. 1. *a*, egg of *Paniscus geminatus* var. *sayi* immediately after deposition; *b*, newly hatched larva of *Paniscus spinipes*. (Enlarged).

THE EGG AND ITS ATTACHMENT.

The eggs (Figs. 1*a* and 6, Pl. XXII) of the two species of *Paniscus*, dealt with this paper, are approximately oval in form, somewhat flattened on the ventral side but distinctly convex on the dorsal surface. Individual eggs are about one millimeter in length and one-half millimeter in greatest width, and may vary in color from a light brown to a jet black. At the posterior pole is a spiral-like petiole by means of which the egg is attached to a host larva. This petiole is enlarged near its base and then gradually tapers to a blunt point at its distal extremity. Shortly after oviposition the petiole is opaque, very elastic, and may be stretched beyond the entire length of the egg, but upon release it recoils into its original corkscrew shape.

Within a few minutes after oviposition the petiole may quite easily be pulled loose from the skin of the host larva. Later, however, it becomes so firmly fixed to the larva that removal without tearing out a part of the adjacent larval integument is impossible. When an egg several days old is detached from a larva the petiole appears dark and knobbed.

When the egg passes down the outside of the ovipositor the petiole apparently remains within a groove, and enters the body of the host larva through the incision made by the ovipositor. Chewyreuv (6) thought that the different species of *Paniscus* attached the petioles of their eggs under the skin of the host larvæ in various ways, and from his own observations and the illustrations of another writer he came to the conclusion that a noose-like arrangement of the petiole was characteristic of the species *Paniscus testaceous* Thoms.

Chewyreuv (6) states that the eggs of *Paniscus* always contain well developed larvæ when deposited and therefore belong to the group of viviparous or ovoviviparous insects. The species mentioned in this paper are sometimes, though not invariably, ovoviviparous. Some eggs hatch within a period varying from a few minutes to a half hour after being deposited and evidently contain fully developed larvæ, while others, which pass through an incubation period of from six to eight days before hatching are apparently deposited in an undeveloped condition.

LARVAL LIFE.

The entire life of a *Paniscus* larva is spent on, and at the expense of, its host. When ready to hatch the egg splits along the ventral surface for a part of its length and the head and anterior segments of the larva push through the opening (Fig. 1, *b*), while the posterior end remains attached to the inside of the egg shell by means of a number of short, sharp spines. The mouthparts soon become fastened to the body of the host larva and in this position the parasite larva feeds and grows. Strickland (8) states that as the parasite larva increases in size, a shifting of the feeding position becomes necessary, but its posterior end still clings to the old egg shell. These observations have been confirmed by the writer.

Larval growth is most rapid in the later stages. During the earlier larval stages of the parasite the host remains alive in a mature or pre-pupal condition. It is quite probable that the *Paniscus* larva feeds upon the fat bodies and blood, and by the time it reaches maturity the contents of the host have been sucked dry and nothing remains but the flabby skin and head capsule. The *Paniscus* larva then detaches its posterior segments from their position on the inside of the old egg shell and proceeds to spin for itself a cocoon, within which it pupates and then transforms to an adult.

The larva of *P. geminatus* var. *sayi* molts four times while adhering to the body of its host and at the same time maintains its hold on the old egg shell. Each molted skin is not lost but simply shrivels back toward the egg shell where it remains attached. Examination of an egg shell after a full grown larva has just left it will reveal the four cast skins with head molts attached (Fig. 5). Within the cocoon a fifth molt takes place, prior to pupation. No excrement seems to be voided until after the larva has encased itself within its cocoon.

CONSTRUCTION OF COÇOON.

The cocoon of *Paniscus* is elongate oval in shape, about seventeen millimeters in length and seven millimeters in width, black in color, and is constructed of very tightly woven threads spun from the mouth of the larva. These threads are woven into such a dense fabric that the cocoon has a shiny appearance except for the few black threads which are rather loosely spun around it as a means of attachment during the early stages of the spinning process. The threads are white when first exposed to the air.

It seems to be impossible for a *Paniscus* larva to spin its cocoon unless confined in an enclosure large enough only to allow free movement. The cell made in the soil by a larva of *Heliothis obsoleta* Fab., prior to its final destruction by a developing *Paniscus* larva, is apparently ideal in shape and size for the construction of such a cocoon. Probably the cell formed by cutworm or army worm larvæ when they pupate would be equally satisfactory. Under laboratory conditions it was possible to induce a *Paniscus* larva to spin its cocoon by placing it within an artificial cell made in cotton. The writer could never induce a *Paniscus* larva to "spin up" successfully in an empty tin box, though this was tried repeatedly. Under such conditions the parasite larva developed to maturity on its host and then attempted to spin a cocoon. A number of threads were spun across a part of the bottom of the box and perhaps along one side and the larva worked very industriously, only to meet with ultimate death, apparently unable to construct a cocoon in so large a space.

SUMMARY.

1. *Paniscus spinipes* Cushman and *P. geminatus* Say. var. *sayi* Cushman may be successfully reared under laboratory conditions.
2. When so reared, females of both species readily oviposit upon larvæ of the corn earworm, *Heliothis obsoleta* Fab., but exhibit a decided preference for either cutworm or army worm larvæ. The choice of host larvæ provides a subject for interesting investigation.
3. The life history and habits of these two species in confinement are very similar.
4. Females of both species reproduced parthenogenetically.

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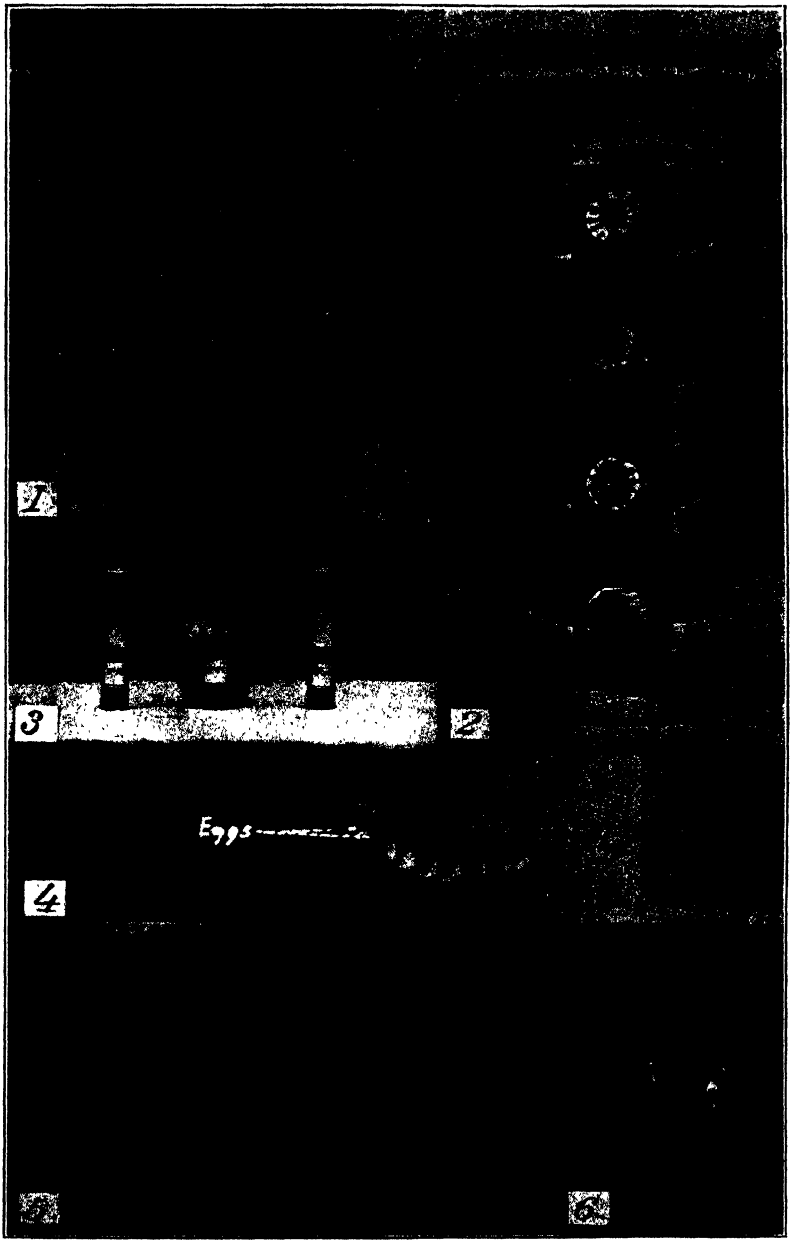
EXPLANATION OF PLATE.

PLATE XXII.

Fig. 1. Adult of ***Paniscus geminatus*** Say, var. ***sayi*** Cushman. (Enlarged).
Fig. 2. Type of cage used in experiments on ***Paniscus.***
Fig. 3. Types of glass and vials used for rearing ***Paniscus*** larvæ.
Fig. 4. ***Paniscus*** eggs attached to larva of ***Heliothis obsoleta*** Fab.
Fig. 5. Old egg shell of ***Paniscus geminatus*** Say, var. ***sayi*** Cushman, with four molted skins and head casts. (Enlarged).
Fig. 6. Egg of ***Paniscus.*** (Enlarged).



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SYMPOSIUM:—NEEDED LINES OF INVESTIGATION IN AMERICAN ENTOMOLOGY.

INTRODUCTION.

E. D. BALL.

The Science of Entomology has made wonderful strides in the past generation. The economic situation has been entirely rebuilt and changed from an empirical art to a scientific profession. The systematic side has prospered and gradually broadened until in many lines it rests upon a sound morphological and biological foundation. Man made catagories are rapidly being altered into the derived groups of a truly phylogenetic conception. The biological and ecological foundations are being laid and the work in the older fields of morphology and physiology revived. With that showing of progress research still needs much of stimulation and direction. Your committee evidently recognized this need in all lines and provided speakers for each phase. There are, however, other factors that are not specifically considered under these headings, and which possibly need the major emphasis at this time.

First.—What we need is not *more* research, as much as, better research—true research, if you please—research that seeks to ascertain the fundamental factors that control a given set of occurrences. We need that type of research that not only gets result, but explains the why and wherefore.

When an insect is rampant, it is research to work out an immediate method of destroying the pest, and that is the proper thing to do at the time, but if it stops there it is a relatively puny effort. It is like a man getting his firewood by cutting branches from a tree. The lowest branch may give him a little wood with a minimum of effort, much easier for the time being than cutting down the tree—each succeeding branch as he goes up the tree will, however, become more and more difficult, as he has no proper foundation from which to work and finally he will reach a point where the tree will have to come down. What a saving of needless labor it would have been to have felled the tree in the beginning and hewed the branches from the prostrate trunk. Many of the branches, in fact, would have been broken off in the fall. So, it is in scientific research; to meet the immediate emergency, we chop off the nearest and most available branch and for the most part we have continued chopping branches of immediate control until the great problem before us today, is to bring down some of the solid trunks of biological principles. When we have an abundance of solid wood, we will find that the major portion of those branches are of no consequence at all.

When the mosquito bites you, the first thing to do is to slap; the next thing to go out and find the can in which she developed and kick it over, and keep on kicking until every can and breeding place in the surrounding region has been cleaned up. Thousands of generations, however, sat and slapped their lives away before anyone developed the energy to kick, and even today—there are many more slappers than kickers.

If there is an alarming and unusual outbreak of an insect, there must be some factor or more often factors responsible for the changed situation. A real research program will include a search for these controlling factors, and the particular variation that was at the time responsible for the upsetting of nature's balance. With these factors known, it will often be possible to anticipate an outbreak, and either prevent its occurrence or arrange in advance for effective control.

Take the codling moth as an example—this insect is world wide in distribution—a pest from the earliest cultivation of the apple, and still a major pest with many unknown factors. Nearly every experiment station in the apple belt had carried on investigations, but, how few of the hundreds of these investigations have made major contributions to the fundamental problem. There have been lots of slappers, and few kickers; lots of branch trimming and few trees felled.

This insect has two generations throughout the greater part of the commercial apple belt, and the behavior of these two generations varies widely, therefore, the best methods of controlling the two generations will vary as widely. This seriously complicates the problem, and yet, in spite of the knowledge of this situation 99% of the investigators instead of ascertaining its efficiency on each generation separately have been content to use the final results of the season's work, as a test of their methods. The first time the broods were separated, a cheaper and more effective method of control was developed, and yet, in trying to further improve this method, many of the investigators have gone back to the old practice of using the final results.

This reminds me of a man in the South last season, who sprayed his bean crop with calcium arsenate, nicotine sulphate, bordeaux mixture and derrisol, and succeeded in controlling the bean leafhopper. Now, he wants to know what to spray with this year. He controlled the hoppers, but he has four guesses as to what did it, and the writer after studying the situation carefully, has a fifth.

A considerable group of investigators representing three Government Bureaus, and two State Organizations, met the past year and worked out an elaborate and very complete program of investigation of a certain problem with reference to poisonous residues remaining on food products. The carrying out of this program involved a long series of spray tests, daily observations and records; a large number of samples taken and chemical analysis made, all of which were necessary to its solution. In the planning of this experiment, the very latest and most up-to-date knowledge of all phases of this subject was utilized—nothing left undone that could be anticipated as bearing on the completeness of the experiment. The work was done—a large amount of valuable data secured—and a goodly branch was hewed off the tree of entomological knowledge.

Soon after this work was completed, a single investigator, working in a crude laboratory, attacked one of the fundamental factors of this problem, and soon discovered that the spray used in this elaborate experiment was less than 50% as effective as another well-known compound for that particular work. By laying his axe to the root of a sapling instead of a branch of a big tree, that young man let a ray of permanent light into the gloom of the entomological woods.

The next step then, is to go back and do the big job over with the right compound—but is it? By that time let us hope the young man has tested the efficiency of different methods of application and, if, as is very likely to happen, he should find that a different method from the one employed gave 50% better results, then nothing would have been gained by the second effort, and yet, you must remember that the best available knowledge of both materials and methods was used in the planning of the experiment. When will we learn to do fundamentals first and applications afterward? Seventy-five percent of present expenditure of time and effort could be saved.

Second.—We need more cooperation—and again it is cooperation in working out basic facts that is needed. Fully 90% of our present cooperation is in eradication, quarantine, regulatory or reporting lines, and only a measly 10% is in lines that add to the sum total of our knowledge. If cooperation of the biologist, ecologist, physiologist and the economic entomologist went no further than to outline sound projects, it would accomplish wonders. If such a program had been in operation for the past ten years, one-half of the present activities would have "died a borning" as our grandmothers would have said.

The systematist should first study the limits of variation in a few species or a small group, and cooperate with the morphologist, the biologist and the student of distribution, in developing basic principles to be applied to the larger aggregates.

If this program had been followed in the past, there would be far less monographic misfortunes cluttering up our shelves and handicapping progress.

The writer recently worked over a genus that has been revised three times in the past few years, and decided that what it needs now is revision. The first reviser apparently did not know what a genus was;

the second was equally hazy on the limits of a species, while the third apparently had a supreme and child-like faith in the accuracy of the printed word—and none of these are characteristics of those whose works endure the ages.

Third.—We need more of the *Spirit of Research*—the inquiring mind—the spirit that subjects all statements to analysis before acceptance—the spirit that holds all truths as simply the best deductions from the evidence available but subject to modification at any time on the basis of new evidence. Such a spirit welcomes constructive criticisms and invites cooperation. Such a spirit grows and expands with the increasing knowledge and is ever young and up-to-date.

This is the day of mental tests, here is by far the best single test of the research mind that the writer has encountered. It was new to him, though doubtless old to many of you. It is a perfectly fair and complete statement of a simple problem without a sign of a catch or any play upon words. One need consider nothing except the problem involved.

"A man purchased a set of 12 volumes, each volume containing 200 pages or 100 leaves; each leaf one hundredth of an inch thick, so that each volumne, omitting extra pages and covers, was exactly one inch in thickness. He placed the 12 volumes on a shelf in a normal way, with volume 1 on the left, followed by volume 2, 3 and 4 to the right in regular order. Sometime later on examining them he found that a bookworm had eaten a hole in a straight line from page 1 of volume 1, to page 200 of volume 3. Omitting consideration of the extra pages and covers—how many inches of books did the worm eat through?"

Just take that home and try it on your graduate students—if they answer three, console them by telling them that there have been many others. If they answer one, or better yet, do not answer at all but get the books and see for themselves, rejoice, for you have the material on which to build.

Someone has said that the great scientific leaders of one generation, are not the sons, but the *students* of great leaders of the previous generation, and therefore, grand students and great grand students of the leaders of ages past. This raises no question of heredity, but asserts that the power to inspire with the research spirit and the wisdom to equip the growing mind with the fundamentals in principles and methods necessary to enable it to function efficiently is the gift supreme in the development of science.

It has been frequently noted that there is a marked difference in the ability to select and solve major problems manifested by students of different laboratories. If a fourth need in research were to be suggested, it would be to discover the human qualities that make for outstanding leadership in research, and possibly even more important, those rarer qualities that make for exceptional ability to attract and inspire research students. Because, be the need for research ever so great, in the last analysis it is upon the ability, equipment and inspiration of the research workers that the final outcome depends.

TAXONOMY.

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The taxonomic study of insects is the oldest and most fundamental line of investigation in all entomology, but it is evident from recent papers and reports of committees and from the general attitude of entomologists as a whole that it has not been so considered in recent years. You remember that at the last International Congress of Entomology[1], resolutions were passed pointing out the importance of taxonomic work and recommending that universities recognize its value and consider theses on taxonomy worthy of merit. At a recent symposium held in London[2] there was a long discussion about the value of taxonomic work. Prior to that, taxonomy and its relation to other lines of investigation had been discussed by retiring presidents[3] and at symposiums[4] before other societies. All this agitation about taxonomic investigations evidently shows either that there is something the matter with the taxonomic work that has been done, or that so few people have entered this field that their work is not covering the ground adequately. In any event we may feel certain that the science of taxonomic entomology needs to be overhauled to some extent. I am not an accurate enough diagnostician to point out all of the sore spots, but in the following remarks I shall try to indicate some places where improvement can be made. Some of the points I wish to emphasize have already been brought to your attention by Dr. Howard[5] in his admirable address two years ago, and I recommend that you reread this address periodically for stimulation and suggestions. Some of these and other points now suggested have been mentioned by others, but a repetition may emphasize their importance.

The subject of this symposium calls, if I interpret it correctly, for definite suggestions as to where taxonomic investigations are needed at present, and perhaps it is well that it has been so limited. But if I were to confine myself to this alone I should either be through when I had said that taxonomic investigations are needed in all groups of insects, or else I could read you a list of the groups of insects and set you all to wondering whose scheme of classification I was using, and cause you to lose sight of the main object of the symposium. I know of no group of American insects which is sufficiently well studied to form a model unit, on which further investigations are not needed.

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[1] The Third International Congress of Entomology (Zurich), July, 1925. These resolutions are republished on pages 476 and 477, in reference given in footnote 2.

[2] See Annals of Applied Biology, vol. 13, no. 3, August, 1926, pp. 466-485.

[3] Gahan, A. B. Proc. Ent. Soc. Wash., vol. 25, no. 3, March, 1925, pp. 69-78.

[4] Rohwer, S. A., Baker, A. C., and Ball, E. D., Jour. Wash. Acad. Sci., vol. 16, no. 3, Feb. 4, 1926, pp. 53-67.

[5] Howard, L. O., Annals Ent. Soc. America, vol. 18, no. 1, March, 1925. Republished in Ann. Rept. Smithsonian Inst., 1925, pp. 355-372.

It has been pointedly said by a well-known student of insect taxonomy that the best way to find out how little you know about a given group is to "revise" it, and that the influx of material following publication will convince you that the revision itself needs revision.

With this in mind, I shall present as an introduction, to what seem to me to be some of the more pressing taxonomic problems, some of the needs of taxonomic work as a whole.

Before attempting to outline these needs, may I first set forth the object of taxonomic work as I see it? Briefly, it is the arrangement of insects in a phylogenetic sequence based on a knowledge of their morphology, ecology, physiology, and development, and it should thus include the idea that a species is an aggregation of *living* individuals which in nature react in a more or less uniform manner to the same stimuli. For the present, at least, I think we must assume that similar reactions to the same stimuli cause the development of similar characters and characteristics, and therefore that we can best continue to base our classifications on morphological differences. We should not, however, overstress or misinterpret morphology. Striking morphological differences or similarities may not be the real key to relationships. When morphology is properly interpreted, however, I feel sure that we will find that the sequence produced by such interpretation will harmonize with the arrangements based on an analysis of the ecology, physiology, and development. No taxonomic study should be undertaken without a realization of the importance of development and of relation to environment.

Perhaps 80 per cent of all the taxonomic work on American insects has been done by amateurs, or people who have classified insects as a hobby. To these students entomology, and especially that type of entomology which until recently has been called "economic entomology," is greatly indebted. Without their aid "economic entomology" would have been greatly hampered, and I do not wish in any way to belittle their achievements. I do feel, however, that the time has come when we must have a more profound respect for taxonomy and look to the building up of a corps of professional taxonomists. The science of the classification of insects has become so vast, there are so many forms already described, and so many of the species have an extensive distribution, that it is unsafe and inadvisable for us to continue to encourage taxonomic investigations by people who do not have access to large collections and large libraries. Taxonomic work in the futue must be founded on abundant material collected over a wide area. Groups must be studied from the standpoint, not of a limited region, but of continents, and, better yet, the world as a whole. So much has already been done in many groups that it is practically impossible for private individuals to obtain all of the literature, and I therefore feel that the day of the amateur taxonomist is—and justly so—rapidly passing. It is no longer desirable to consider as taxonomy the sorting of specimens on the bases of minor differences. The early workers were justified in doing this, but a deeper study must now be made.

If taxonomic entomology has not large openings for amateurs, and if we insist that it must be based on more intensive studies, then we must expect and demand that the workers entering into this line of investigation be more broadly and thoroughly trained than they have been in the past. They must have a keen appreciation of the underlying laws of nature which permit an understanding of phylogenetic development. They must be well versed in those sciences which are handmaidens to taxonomy, such as morphology, cytology, embryology, and paleontology, and they must not forget the need of an appreciation of the fundamentals of geographical distribution. The taxonomist of the future, therefore, must be well and broadly trained. He must be able to recognize that his science, and the good that he does to science as a whole, will depend to a large extent on his ability to keep pace with the work that is done in other fields and to coordinate this work with his. Furthermore, he must use the results obtained from these other investigations and incorporate them into his publications. A knowledge of the few sciences mentioned above is not sufficient. Many of us are quite aware of the present tendency on the part of certain workers to apply mathematics to taxonomic studies; and while some of us fail to see the application of mathematics to all phases of taxonomic problems, we must admit that in many places it has a decided usefulness.

If the estimate that there are at least 640,000 kinds of described insects is correct, and if we concede that ultimately approximately 5,000,000 species of insects will be known in the world, we may be somewhat appalled at the number of forms that should be described to make our knowledge complete. Those who have been describing so many hundred new species each year may feel proud and to some extent satisfied that they are doing their bit to help catalogue the world's insects. To some extent I can sympathize with them. Years ago I used to look with considerable pleasure on a new species. Now I am quite sure that for the good of the cause the time of "scouting" in taxonomic entomology is past. Instead of describing so many more new species, we should devote more effort to coordinating and summarizing what is known about those already described. Although papers containing only miscellaneous descriptions are necessary, I have scant respect for them. I have, on the other hand, the highest regard for those papers which are of a revisionary nature. Theses which review what has been done, coordinate it, and augment it by a study of all the additional material the writer can examine, hold promise of being real contributions.

May I emphasize this by an illustration? I do not believe that one is contributing much to the science merely by just describing another *Halictus* when there are already probably six or seven hundred described from all the zoogeographic regions, and when many of these cannot be recognized from descriptions. It would be a comparatively simple matter to sit down and prepare descriptions, without any great danger of making synonyms, for probably 40 or 50 new species of Halictus occurring in North America. To do so would only be making more difficult the work of our successors. The only satisfactory way to treat the *Halictus* of North America is to coordinate those species which have been characterized with those not characterized, and make a comprehensive revisionary paper which will not only clearly set forth the distinguishing characters of the species, but will give us some definite knowledge as to the distribution and seasonal occurrence of those which are described. If I am correct that this "scouting" in taxonomy is no longer justified, and you all agree with me, we will not have any more of those interesting competitive experiences that have existed in the past, when the workers have hastened to describe new species in order that the types might be in their collections or their museums. And that is not all, for could we eliminate the selfish competition we could then develop much more that necessary adjunct to all scientific endeavor, cooperation.

In most lines of entomological investigation, as well as in many of the other sciences where the largest advances are made, there have been cooperation and coordination of work, and not just a hit-or-miss idea of sorting and arranging certain facts. Taxonomic investigations have not been coordinated, and I am sorry to say that cooperation is only beginning to manifest itself. Duplication of effort in taxonomic work is often appalling. Within the last 18 months I have known of six students who wished to undertake revisionary studies on the fleas of North America. Each one of these individuals had devoted considerable effort to building up a local collection, and gathering together literature and a bibliography. Any one of these workers would gladly have devoted the same amount of preliminary effort to gathering materials on another group. A freer cooperation between those directing or suggesting problems would have at least discouraged this duplication of effort. Some clearing house where records could be kept of taxonomic problems undertaken, and perhaps a periodic bulletin telling others of these investigations and giving information on recent collections of insects, would be of considerable help and might prevent duplication of effort and stimulate cooperation.

Most of the work that has been done in the past on the classification of insects has dealt with the adults. Our classifications are all based on characters selected from the adults, and only recently has any effort been made to study in a comprehensive way the immature stages. With practically all insects the injurious stage is that of the larva or nymph, and I believe that it is extremely important that investigations be made into the classification of the immature stages of all orders. The need for investigation of the immature stages stands out most strikingly, however, in those groups in which the metamorphosis is complete. There is very little resemblance between the caterpillar and the moth, yet there is sufficient resemblance between the nymph and the adult grasshopper to permit in many cases a definite association of characters. The type of work that is being done by Malloch and Greene in Diptera; by Hamilton, Craighead, Richmond, Böving, St. George, Champlain, Wood, Cotton, and others, in Coleoptera; the studies of Dyar, Forbes, Mosher, and Heinrich in Lepidoptera; and those of Yuasa, McGillivray, Parker, and Middleton in Hymenoptera, have gone a long way in the right direction. Still we have only scratched the surface. Valuable hints on phylogeny, necessary information as to how to recognize those stages which are injurious, will be gained by the comprehensive study of the immature stages. While we will all agree that we should make studies on the immature stages, I do not believe that many of us have cooperated towards making these studies possible. The study of the immature stages must be preceded by the amassing of material. Without definitely associated larvæ and adults, more harm than good may be done by attempting to do much work on the immature stages. Every one of us can render great service by preserving immature stages which can definitely be associated with adults. The insect collection in the U. S. National Museum is outstanding in the quantity of material of immature stages it contains, and yet we are finding that this is woefully inadequate to carry on the types of studies which we wish to make.

The study of the immature stages is such an outstanding needed line of investigation and offers so much of practical value that it seems advisable to add a word of caution lest investigators in this field lose sight of the whole. A study of the immature forms alone may be likened to a study of only a part of the organism. Our classifications should be built on a study of the whole insect, its structure, behavior, and history. The magnitude of the task offers some practical difficulties in treating the whole problem in one publication, but the investigator should not lose sight of the desired result.

The subject of our symposium limits our discussion to the needed lines of investigation in American entomology. But this is hardly fair to taxonomy, for the specialist who attempts to confine his studies to American insects will not be rendering the fullest service. Man and his civilization have moved and are moving many insects. Some of these have found and may again find access to our country. A prompt recognition of these is of great importance to man, his crops, and his animals. Who is going to safeguard us from these unwelcome enemies if the taxonomist confines his studies to native insects? The taxonomist must have a world viewpoint, and as the work progresses and we appreciate more the principles outlined above it is hoped that taxonomic work will have a much broader outlook and be world-wide in scope.

Those of you who have done real taxonomic work are undoubtedly familiar with many of the perplexing problems which confront the taxonomist. What are the limits of variation in a species? What characters may be relied on? Is a certain difference caused by the host or does it represent the effect of a particular region? These and many more questions confront the taxonomist every day. How can they be solved? Will the study of large series from widely separated regions and reared from a number of hosts furnish the answer? Yes, such a study will help! But another plan which would furnish a more satisfactory answer would be to study the progeny of known parents. Careful rearing of specimens of known pedigree on a number of hosts and under a wide range of ecological conditions would help immensely.

Experiments of this kind conducted on a few forms would furnish some criterion which would aid in solving the same problem as it occurred in other groups. Could not some graduate students rear and make critical analysis of the variation in the progeny of known parents? Such a study offers ample opportunity to test one's ability to do independent research and would undoubtedly offer abundant test of one's initiative.

Looking over the groups of insects which are badly in need of revision, I have selected only a few examples, and as I read the list you will undoubtedly note that I have chosen mostly those groups which have a direct bearing on American agriculture. This is not because the other groups do not require study but because the need of revisionary work on the economically important groups is being constantly impressed upon me and also because it is necessary first to investigate those things which affect our own welfare.

In the Coleoptera we need comprehensive revisionary work in the following families: Scarabaeidæ, Chrysomelidæ, Coccinellidæ, Scolytidæ, Cerambycidæ, Buprestidæ, and Curculionidæ. In Lepidoptera the Pyralidæ, Noctuidæ, and Geometridæ might be the first groups to be considered; in Hemiptera, the Miridæ and Jassoidea; in Diptera, the Tachinoidea and Trypetidæ; in Orthoptera, the Acrididæ; in Hymenoptera, the parastic forms and the sawflies; in ectoparasites, the parasitic mites, especially those of the genus *Sarcoptes*.

I have mentioned only a very few of the lines of investigation in taxonomic entomology and have made no effort to outline these in detail or to defend the investigation suggested. The outlining of abundant problems in taxonomy would be easy and it would be almost as easy to set forth arguments why the investigation should be done. But neither of these has a place at this symposium. Furthermore, all taxonomists know where and how to start a problem and they all realize that a satisfactory detailed outline cannot be followed. Only a general outline can be prepared, for as the work progresses the details have to be modified to suit the needs and the material available.

I hope I have succeeded in pointing out enough places where investigation is needed to convince you that the field of entomological taxonomy offers wonderful opportunities. I trust that I have been more successful and have conveyed to you the impression that the need for investigation into the classification of insects exists in all the major units and that there are problems enough to keep hundreds of workers busy for years to come. To describe all the kinds of insects which will eventually be known in the world will take, at the present rate, over five hundred years.

But that is not all I hope for. I am anxious that you gather some of my desire to make the taxonomic work of the future more thorough, more comprehensive, and thus more useful. If I have been successful in this, we can all cooperate and make the taxonomic work on insects in America more efficient and bring to it the much needed facilities for publication and indexing of the work of others. And more than that, we can obtain more and better-trained workers, larger collections, and better laboratories in which these new investigators may study.

INSECT PHYSIOLOGY.

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INTRODUCTION.

Insect Physiology, by the nature of its content, does not lend itself readily to geographical distinctions. Hence my contribution to this discussion will contain little that is characteristically American in its bearing. As a subscience, the physiology of insects stands at the threshold of its development despite numerous scattering, physiological investigations of the past which have used insects as material. One seeks long, perhaps in vain, to find any aspect of the subject which would not, on scrutiny, yield opportunities for extensive contributions to our knowledge. Hence my task is one of choosing *what* to discuss. In these days of vigorous research one finds his own field of intimate knowledge hemmed in by increasingly extensive expanses of outlying territory which must of necessity be known but dimly and from a distance. I have assumed, therefore, that our subject does not imply necessity of a complete survey of the assigned field; that if my discussion concerns itself with research opportunities which have appeared directly or indirectly from my own investigations and about which I can perhaps claim some slight knowledge, I will approximate the expectation of those who planned this program.

Since at present I am investigating certain aspects of insect respiration, I shall use that subject as the entering wedge.

RESPIRATION.

Respiration in insects has long intrigued the interest of investigators. Its fundamental role in the maintenance of life, the innumerable modifications of accessory organs, the versatility of insects in utilizing direct and indirect sources of oxygen supply, the intimate relation of respiration to economic problems—all these have done much to direct attention to this field. Nevertheless, the subject deserves intensive study at the present time.

Functions of Organs.

As is often the case, morphology has here led far in advance of physiology. Functions of some well known organs are imperfectly known and differences of opinion common. Indeed, the conclusion that certain organs function in respiration at all is apparently inferential. (Example: Ventral eversible sacs of Thysanura, Perla, and Scolopendrella; recent expressions of doubt (Remy, 1925) as to respiratory function). The existence of inspiratory and expiratory spiracles is still questioned although the most recent work (Lee, 1925; Wrede, 1926) seems to show a certain agreement. Whether unharmonious results are due to faulty experimentation or whether they arise from the use of different species and different life history stages, only future research will tell. Many other similar cases might be cited. A series of critical experimental investigations involving a wide range of species must be made before our knowledge will begin to take on a dependable form.

Reduced Organs.

That the truly apneustic and holopneustic types of tracheation are connected by many forms of intergrade (sometimes grouped under the term Hemipneustic) is common knowledge. The degree of reduction of both spiracles and tracheae is, in different insects, a matter of great variation and the line of demarkation between the two types is elusive. I have long doubted the truth of some current actual or implied statements, that reduced spiracles and tracheae are either functionless or ineffective. The case is easily settled where it can be shown that there is complete, unqualified morphological closure, but anything short of this is worthy of critical investigation. Takatsuki postulated waxy secretions in the tracheae of mosquito larvae which act as barriers but Hacker (1925) failed to confirm these results.

Reduction of the whole or a part of a tracheal system does not necessarily preclude functioning (Welch, 1922). It may result in spiracles and tracheae no smaller than those of some minute holopneustic insects. Furthermore, it has been shown (Krogh, 1920a, 1920b) that there is no difficulty in the ventilation of such a system since diffusion alone is an effective factor in tracheae of extremely small diameters. The whole question of apneustic, and hemipneustic tracheation, must be reapproached by means of modern morphological and experimental methods.

Function of "Gills."

Time honored conceptions concerning the functions of certain organs, have too long escaped modern scrutiny. Various adaptive organs of aquatic insects are thought to be respiratory and often called gills. Conceding that undoubtedly some are true gills, others need re-examination. Fox (1921) claims to have shown that in a red Chironomus larva no more oxygen is absorbed by the anal gills than by the general body surface and "no oxygen at all absorbed by the ventral gills." Here is a direct challenge to a very common interpretation of long standing and likewise a tacit interrogation as to other similar structures. So far as I have been able to discover, no one has repeated or extended Fox's work. Remy (1925) in his large work on respiration in invertebrates makes use of a number of insects, including Chironomus larvae. Unfortunately his method failed at this particular point and no definite results were obtained. He makes no mention of the work of Fox.

Suspicion has also fallen upon the role played by tracheal gills. Cuenot (1925) claims, on the basis of experiments on naiads of Ephemerida and Odonata, that either these organs do not function in respiration at all, or at best are minor adjuncts to other more important receptors of dissolved oxygen. Remy (1925), however, gives them a higher rating.

Carbon Dioxide Elimination.

The method of carbon dioxide elimination has long been a matter of disagreement. Krogh (1913) and others have held that in certain insects CO_2 must be eliminated by means other than the tracheae, while Buddenbrock and Rohr (1922), Lee (1925) and Wrede (1926) present evidence to show that the tracheae are the avenues of elimination. Dewitz (1890), Muttkowski (1920), Lee (1925) and others have demonstrated the possibility of CO_2 diffusion through the integument but the degree to which it actually takes place in the living insect is still a matter of uncertainity. The occurrence of calcium carbonate in the Malpighian tubules and the fat-body (Imms, 1925) has been thought by some to be due to the neutralization of some of the CO_2 in the blood, although proof seems to be lacking.

Anaerobic Respiration.

The existence of insects, as well as certain other animals, in the bottom of deep inland lakes under conditions of complete absence of dissolved oxygen, (summer and winter stagnation periods), is a well established fact. The same ability to thrive in the absence of free oxygen seems to be true of many internal parasites. The source of the oxygen required in the internal metabolic processes is unknown. Intramolecular respiration has been postulated; catalase determinations have been made; chemical methods of increasing resistance to reduced dissolved oxygen have been tried; and Cole (1921) claims that minute amounts of an oxidizing substance formed in decomposition of plant tissue under oxygenless conditions may possibly be atomic oxygen which might serve as the oxygen supply for these insects. The problem still awaits solution.

Other Problems in Respiration.

(1) Sources and roles of gases, particularly those in the tracheal system sometimes referred to in the literature as Air of Transformation (Muttkowski, 1920) are still more or less of an enigma. Keilin (1924), observing that in aquatic apneustic insects on hatching or emerging from a moult have the tracheal system first filled with fluid, then by a gas, holds that the former is absorbed by surrounding cells and the space thus vacated immediately filled by gases diffusing from the blood. "Internal and external inflation" gases still remain unsolved. Likewise, those gas accumulations which appear in certain aquatic insects on prolonged exposure to slightly unfavorable conditions are yet to be explained.

(2) Differences in oxygen requirements constitute a subject of uncertain status. Gill area, gill number, or gill absence can not be taken as dependable criteria of oxygen demand. Dodds and Hisaw (1924) found a definite correlation between gill area and oxygen content in certain Rocky Mountain mayfly naiads, but on the other hand numerous opposing examples prevail, as for example, the larvæ of two closely allied of the genus *Nymphula* (Lepidoptera) both living in the

same environment (Welch, 1916; 1922) both of same body size, but one with more than 400 gill filaments, and the other with none at all. Entomological literature contains mis-statements, direct or implied, as to the supposed limiting effect of oxygen supply. A much repeated one explains the universal restriction of *Simulium* larvae to running water because that water alone has a sufficiently high dissolved oxygen content to meet the high oxygen requirement of the larvae, when as a matter of fact, the idea is fallacious as shown by the unpublished work of one of my graduate students.

The next subject naturally follows in the wake of a respiration discussion.

INSECT BLOOD.

Investigations on the morphology and physiology of insect blood are specially urgent because of the recent opening up of at least two seemingly prolific fields.

(1) Respiratory pigments or proteins.

The older idea of the complete independence of circulation and respiration in insects is toppling, due to recently reported evidences (Muttkowski, (1921a, b, c); Keilin 1925) of chemical substances in the blood and elsewhere which are thought to perform a function similar to that of haemoglobin. Haemoglobin has long been known in a few insects, but the indication that other oxygen carrying substances may occur widely throughout the insect group puts a new face on the whole respiration problem and blocks out a field of investigation which may have important possibilities. Remy (1925) found evidence that the "young leucocytes" in contact with the tracheoles fix oxygen and distribute it to the different tissues; also that the blood plasma may play a similar but lesser role. His method, however, was not designed to identify oxygen carrying substances.

(2) Physical changes in Haemolymph. In this second field a single paper has brought to light possibilities which may be far reaching. Ackerman (1926) working on the problem of the physiological basis of wing production in aphids, found, among other things, that the haemolymph contains four kinds of globules, two pigmented and two colorless lipoid ones; that reduced temperatures cause the lipoid globules to solidify; that both wing production and the solidfication of the fat globules appear to be dependent upon the breaking of the delicate, unstable brown globules; and "that wing production is dependent upon the proportion or concentration of certain substances in the haemolymph as brought to pass by the rupture of the brown globules." This distinctly new point of attack has application more far reaching than the mere problem of wing production in aphids. Even if perchance future research should fail to confirm Ackerman's explanation of wing production, there would still remain his fundamental findings of physical changes in the haemolymph, their interrelations, and their correlation with environmental changes. May it not be that other internal events in insects are concerned in these phenomena. May they not have some fundamental relation to problems of metamorphosis and development,

growth, polymorphism, and nutrition. And do not these findings possibly clear the way for a better understanding of temperature change effects in insects.

NUTRITIONAL PROBLEMS.

Out of the array of possible nutritional problems only two are mentioned.

(1) Influences of Associated Organisms:—For a long time it has been recognized by many investigators that internal symbionts may play some important role in the digestion of food stuffs normally taken by the host insect. The work of Cleveland (1924, 1925 a, b, c) has opened the way to a whole series of needed investigations. By the development of promising methods (the removal of the symbionts by means of certain temperatures, by starvation, and by oxygenation), he has apparently solved the approach to a dependable experimental study of the relation of various micro-organisms to their hosts. Many insects other than termites make some use of woody materials and the extent to which cellulose is available as food can now be investigated. Possibly other forms of digestion are related to the presence of micro-organisms and the same or similar methods may facilitate future investigations.

(2) Dissolved organic matter.—Some years ago Pütter (1907 a, b) proposed that the dissolved organic matter in the water must serve as food supply for aquatic organisms, and by several subsequent investigations appeared to show that many kinds of animals, including Arthropods, make extensive use of these materials by direct absorption. In some cases he got surprisingly large percentages of the nutrition secured in this way. From the outset, Pütter's contention fell, and still falls, upon skeptical ears. Recently, seeming confirmation of his results appears in the work of Esaki (1926) and Krizenecky, and Podhradsky (1924) working with amphibian larvæ. On the other hand, Dakin (1925) performed experiments similar to those of Pütter but with negative results. One of the several objections raised against Pütter's findings hinges upon the actual amount of this dissolved organic matter in the water. Pütter found high values in sea water; other workers (Moore et al., 1912) claimed the presence of no more than one part in one million of soluble material. The whole question has been reopened and given a new importance by the recent work of Birge and Juday and their co-workers (1926) which shows that in Wisconsin lakes the dissolved organic matter is far greater in quantity than in sea water; that it is "ordinarily several times and often many times greater than that in the plankton;" and that "it is as well suited for food as is the organic matter of the plankton" itself. Again the controverted question—to what extent is it actually used directly as food by the various aquatic animals. This is, of course, a problem of wide biological ramifications, but since a great many insects live partly or wholly submerged in aquatic environments, questions relating to the direct availability of dissolved organic foods are equally pertinent to our subject. It is still an open field and merits the attention of investigators.

Body Surface Features.

Notwithstanding numerous scattering papers which deal with the relation of external surface features of insects to surface tension phenomena, one who needs certain kinds of fundamental information as to the chemical or physical bases which lie back of the ways in which liquids relate themselves to body surface, pubescences, and etc. will likely meet with some disappointment. The recent paper by Hacker (1925) presents, among other things, interesting and valuable data on the role played by differential wetting in the life history of mosquito larvae and in their susceptibility to the effects of oil. Much remains to be learned as to why certain liquids wet certain substances; why varying degrees of wetting occur in insect structures; and why the hydrofuge character of some surfaces may be more permanent than others. Body hairs, whose tips are wetable and whose bases are hydrofuge have been postulated to help explain certain respiration phenomena in aquatic insects. The very obvious bearings of this subject on problems in insect respiration, insect habits and insect control measures, not to mention other possible applications, make necessary an extension of our knowledge in this direction.

Hydrogen ion Concentration.

Finally, I refer to the role of hydrogen ion concentration in insect biology. For some reason insects have functioned too little in the numerous pH investigations of recent years. Aside from papers dealing with its relation to mosquito larvæ, one searches with restricted success in the literature for specific information on other forms. In fact, the intrinsic value of pH as a single influence is occasionally denied (Hyman, 1925). If anything convincing is to come out of the contention that pH has a specific action on insects, more work must be done in the future. Likewise, its role in the internal processes of insects is still in an unsatisfactory state.

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INSECT BIONOMICS.

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The term bionomics, first suggested by Gedder many years ago, means, literally, life and order, or custom, in other words, the science of life or living things. Certainly a broad enough subject for a ten or fifteen minute discussion. All of the other subjects suggested for this symposium might very well be included under the general heading of bionomics; so the only limit I could see to the field I might cover in this discussion is the time limit and the topics suggested for the other writers.

Insects probably first interested primitive man on account of their presence on his body where they interfered, more or less, with his peace and his comfort. Then began the study of methods of insect control—economic entomology, if you please. At least one of the control of methods developed at that time, or even earlier, is still in use and may be observed at almost any time when one visits the anthopological cages in our zoological parks. In more civilized communities this method is modified somewhat in as much as the fingernails, instead of the teeth, are used for crushing the prey.

Early man soon noticed that some of these pests seemed to confine their attention to the head of the victim, hiding away, when not busy, in the long shaggy locks, as other beasts of prey would hide away in the thick forest glades. Others were more common on other parts of the body, taking refuge, when disturbed, in the folds or crude seams of the primitive clothing. These two forms looked alike but their habits were somewhat different and the question soon arose as to whether they were really the same kind or different kinds of pests. So the study of Taxonomy arose and from that time to this the age old question as to the identity of the two forms has been discussed and it is still unsettled. In this study many other branches of the broad subject of entomology have been developed. Do the two forms differ any in structure—morphologically? Certainly their geographic distribution would seem to favor the hypothesis that they are different species.

Their relations to their environment, their ecology, too, must be considered as well as their physiological reactions to the blood that may be sucked from the veins in the skin on the head or on the body.

Then comes the philosophical consideration of all of the phenomena observed—bionomics. How has the insect responded to the influences of environment? How has it adopted itself to its particular mode of life. What factors have determined the size, shape and color of the little pest and how have these factors wrought their transformations? Are the activities of this insect merely responses to chemical stimuli—tropisms—or are they due to reflexes or instinct or reason? These are the things that the students of bionomics are supposed to settle. About all that I can do in this brief paper is to emphasize, somewhat, some of the topics suggested in the last group of questions.

To live successfully means to be well adapted to the environment. An animal not well adapted must soon become so, or lose out in the struggle. Insects are the most abundant of all living creatures because they are able to adapt themselves so quickly to new conditions, or to take advantage of any changes in their environment that may be more or less favorable to them. Thus we find that species which, under natural conditions, normally fed on some wild or uncultivated plant, rapidly increasing in numbers when they have an opportunity to feed on some cultivated host plant. It is also a well known fact that a change of climate is often good for an insect's health and that they will often thrive and increase abundantly when introduced into a new environment where food is abundant and natural enemies few.

These are well known and well established facts that are generally accepted without question. But do we give these things sufficient consideration when we are studying or planning to study an insect or group of insects? Not only are the habits apt to be changed with a change of environment but pronounced structural changes may also take place and then the subject becomes of interest to the morphologist and the systematist as well as to the ecologist and the economic entomologist.

The study of variation in insects is most important and fascinating. We can not take up the study of any group of insects without having this subject soon forced into our attention. Most of us are content to merely note this, possibly to comment on it, but too few of us go deep enough to try to find out just how much variation there is, much less to try to find the underlying principles that cause and direct these variations. It is true that some very good work has been done along this line, but most of this has been statistical and has not been done by people interested in entomology. The insects have been used because they are abundant and easy to work with. The field is wide open to anyone who wishes to approach it with a wide entomological training and an analytical mind. The field is so interesting and important from many points of view that much more time and energy should be devoted to it.

Another phase of entomology that is receiving altogether too little attention is the subject of communal life, commensalism, and mutual aid. This most fascinating field is almost wholly untrodden except for the few excursions that have been made into it by the students of ants and associated forms. Rich treasures await the explorer in this field.

We are accustomed to think of the subjects of color, pattern and mimicry as things that can be studied successfully only in some far off tropical lands. It is true that some of the most striking and bizzare examples are found in tropical or semi-tropical regions, but we have only to look about us to see most interesting examples of concealing, protective or aggressive coloration or patterns. These can be found in almost all of the orders of insects and the philosophically inclined mind will find here a wealth of material for study and experimentation. So, too, we find many striking examples of mimicry. Not long since I had occasion to try to control the larvæ of a certain sessid moth that was boring into the trunk of young poplar trees. I gave a man a small syringe and some carbon bisulphide and showed him how to use them. Returning some hours later I found that he was making very little progress with the work as the "darned wasps" kept bothering him so much. When I picked up one of the moths, which were his so-called wasps, and showed him how harmless it was, he evidently thought I was playing some kind of a trick on him and he gave up the job rather than associate with such wasp-like looking creatures. Of course we are not all agreed as to the causes of such resemblances or mimicry but the fact that the phenomona occur so often and in such widely separated orders leads most of us, at least, to believe that there is something more than mere chance or accident back of it all. We have come to look with much skepticism on the older theories in regard to the causes of these things and the efforts of American entomologists in this field have been largely critical, rather than constructive, and it is certain that a comprehensive, unbiased study of these questions, in the light of what we already know in regard to the life, structure and habits of many of our insects, would yield interesting and important results.

Another phase of the work scarcely more than touched on by entomologists is the whole field of insect behavior. Tropisms, it is true, have been studied somewhat but much yet remains to be done. When does an act pass from the realm of reflexive or instinctive behavior into the realm of habit or intelligence? Many observations have been made and recorded, but the whole question needs to be re-examined and studied in the light of what we now know about insects and better planned, more scientific experiments made to test out existing or new hypotheses.

INSECT ECOLOGY.

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Ecology is the division of biology that deals with the interrelations of organisms and their environment. We know little enough in an exact way about either organisms or their environment and still less about the interrelations. There are so many ecological problems that frequently one feels that the most important is to know where to begin and what resolutely to defer for the present.

Ecological problems fall readily into two main groups: those primarily concerned with the interrelation of the individual and his environment, and those dealing with communities of taxonomically unrelated organisms. I shall discuss the latter first.

Before going further, I should say that there are no insect communities or insect associations in nature. They exist only as an abstraction. Rarely, for that matter, are there plant or animal communities. Really there are only biotic communities, i.e., groups of plants and animals which are more or less closely integrated into a community system. Frequently on land the most abundant and important animals in such a community are the insects.

These biotic communities have long been recognized. In 1871 Verrill described them for all practical purposes among marine organisms, and S. A. Forbes in 1887 outlined very clearly some of the methods of integration in his admirable essay on *The Lake as a Microcosm.* But it was not until about 1900 that we began to have ecological surveys describing animal and plant "associations" and giving habitat lists of the taxonomically unrelated species found living near each other. Such surveys continue and are valuable in hurried, crude reconnaissance work; the vital problems in insect ecology do not consist in invading new territory and making habitat lists of the species to be found there, or even in working out the succession of different species to be found in habitats arranged in an orderly series according to physiographic age.

One group of vital problems in biotic communities is concerned with the interrelations within the community. Which species are essential? Which are accidental? Which are most important to the continued biotic balance and which are of little importance? What diurnal, seasonal, and other cyclic changes take place within the community? How nearly does the community approach stable equilibrium and what are the factors causing its stability or instability? A knowledge of such interrelationships within the community is essential for a real understanding of animal life in nature and should precede any attempt to tamper with a community by applying artificial conditions made necessary by modern economic work.

These problems can be attacked by three different methods: the statistical, that of natural history and that which may be called the method of synthetic ecology.

The statistical method lends itself to reconnaissance. It requires that collections be as nearly quantitative as possible (the margin of error being known) and that these be analyzed by applying some sort of multiple correlation formula such as the tentative ones proposed by Forbes and by Michaels. By these means one undertakes to determine statistically the closeness of the correlation existing between the species collected. Some will be shown to be accidental, others to be firmly established. Such studies have a deceiving atmosphere of finality. They are an improvement on mere habitat lists, just as those were improvements on the taxonomic check lists that preceded them, but such studies must be supplemented, for they show nothing of the reasons for the observed correlations. Incidentally, there is an excellent opportunity for anyone acquainted with modern statistical methods to develop an adequate formula for dealing with such quantitative collections.

An obvious method of supplementing and expanding the data of statistical ecology is by plain, intelligent observation. We need at the present time such field observations on the interrelations of members of insect communities by gifted observers more than we have ever needed them because now they can be of immediate importance as well as of interest. In the natural reaction from the illogical, disconnected, frequently misinterpreted but always interesting observations of many of the older students of natural history, modern ecology has neglected this important weapon of attack upon the problems of the organization existing within a given community. The method is time-consuming but may yield illuminating results without which the data from modern statistical and experimental work cannot be correctly interpreted, if indeed they can be successfully collected.

I have noticed that, too frequently, one of the major tactical problems in ecology is to persuade persons gifted with powers of field observation to check their results with adequate experiments, or even to use modern instrumentation in determining the actual conditions observed; and on the other hand to get students trained in experimental and statistical methods to do critical observation work.

Such a union of the best in the old and new methods is the aim of the modern synthetic ecologist. He desires to know all that can be known by observation, statistics, field and laboratory experimentation, and by instrumental study of the environment concerning the individual relations of the important species within the community; and from such data, he proposes bit by bit to contribute to an adequate conception of the biotic community viewed as a unit. This reverses the more usual method of the ecological survey which begins with the community and then makes such analyses as time, facilities, and inclination permit.

In order to understand the interrelations within biotic communities, we must have knowledge of the biotic conditions existing at all times of the day and all seasons of the year as well as during the daytime in the pleasantly warm months when field work is a relaxation. Remarkably little is known about winter ecology. This is an important but hitherto neglected field that rapidly repays cultivation. For example,

Dr. A. M. Holmquist has recently reported as a result of his field survey of arthropod hibernation in the Chicago area, that of 329 identified species, about nine per cent of those ordinarily solitary during the summer become more or less closely aggregated in winter. The fact of the existence of such winter aggregations has been long and well known but the extent of the phenomenon in a given population had never before been discovered, and its physiological significance is not yet analyzed. Work upon hibernation is particularly important because frequently the abundance of insects the following year is determined by their success in living through the winter. There has been equally little work upon many of the problems concerned with the sleep of insects.

PHYSICAL RELATION TO ENVIRONMENT.

Exact quantitative studies of all the factors of the physical environment conditioning biotic communities have also been neglected. Such analyses as have been made have frequently over-emphasized some easily measured factor. Thus temperature phenomena were exploited and generalizations made without knowledge, even yet imperfect, of the interrelations between temperature and humidity. But even in temperature work the improvements in technique made possible by thermo-couple developments have reopened the entire field of temperature relations. The old reproach of the natural historians that the animals themselves are more sensitive thermometers than any carried into the field by the instrumentalist, can no longer hold. An excellent example of the type of work needed along this line is furnished by the recent studies of Dr. Chapman and associates.

Recently plant and animal ecologists have been studying exhaustively distribution phenomena in reference to the hydrogen ion concentration (pH) of the soil or water to the neglect of other factors. In fact there has been a constant chase for a possible single factor index which would be a short cut to environmental analysis. In the very nature of the case, this hunt has met with the failure it deserves. The value of different environmental factors must vary in relation to other physical conditions in the environment and with different animals and at different seasons of the year.

One important physical factor that has hitherto been grossly neglected in environmental studies is that of light. For obvious reasons botanists have been more alive to the importance of this factor, particularly since the work of Garner and Allard, but the results have not been extended to insects and the quantitative measurement of illumination in natural habitats has not yet been made except in a few cases.

The recently perfected MacBeth illuminometer makes available a portable instrument applicable to hard field usage. This instrument has stood up under the hard service incident to an extended trip into a tropical rain-forest. . It measures quantitatively the illumination within the visible spectrum but gives only ratios for different wave lengths. Recording instruments have also been described accurate within ± 5 per cent which make this a most promising line of investigation.

Recent laboratory developments that show the marked effects of ultra-violet radiation upon organisms indicate that we must investigate the ecological bearings of this similarly neglected factor.

Many of these environmental factors show diurnal, lunar, seasonal or other cycles. Recent studies upon the relations of lunar cycles to egg-laying of many marine organisms have established the fact that lunar periodicities are more wide-spread than was formerly suspected. This problem has not been adequately investigated among insects. The possibility of longer cycles of insect abundance corresponding to these described by Elton for mammals also deserves fresh investigation, both as to the fact of existence of cycles and particularly concerning their causation.

In this general connection Dr. V. E. Shelford has recently proposed that an endowed laboratory be established to investigate the relations between the environment and biological phenomena with particular reference to the controlling environmental factors in insect abundance, to include not only experimental work but continuous observation on the weather and the actual abundance of animals as determined by qualitative collections, etc. Sufficient progress has been made by Dr. Shelford in his studies of relations between the life history of the codling moth and physical factors in the environment to show that there are marked changes from generation to generation in the responses of these insects. He has succeeded in analyzing the causes of these variations sufficiently to bring them under approximate experimental control. Dr. Shelford finds that in the codling moth kept under identical conditions of temperature, humidity, etc., the pupal stage, for example, may vary as much as 20 per cent in length, due to preceding rainfall, temperature variation, and other similar factors. Abundance appears to be largely controlled by the rainfall of the preceding autumn and by light intensity during twilight hours.

This is a most important lead and should be followed systematically. There is good reason to believe that with competent accumulation and tabulation of data over an extended period such a laboratory could discover the fundamental underlying principles sufficiently to enable it to issue warnings of probable pest abundance; of the most profitable time for applying sprays, etc., of about the level of accuracy now found in weather predictions. Such studies should be carried out on the key members of important communities, hence the necessity for a knowledge as to which members of a community are of great importance; which as was indicated earlier, is one of the immediate objectives in community studies.

These particular studies would have more than merely economic significance for, if successful, they must be based on fundamental relations which would hold, at least in a general way, for all animals.

Another important set of problems is concerned with the relations existing between similar individuals occupying a restricted space. Such groupings are called roughly animal aggregations and their occurrence has long been a matter of record particularly in hibernation and during sexual activity. The factors that lead to the formation of such aggregations was much discussed in the days of the tropism-trial-and-error controversy. The neglected element of this situation has been the lack of information concerning the physiological effect of such aggregations upon the aggregants.

Current belief appears to be that, aside from sexual relations and colonial insects, the crowding caused by these congregations is harmful due to one or more of the following factors: increased concentration of excrement, decreased available food per individual, increased interference, with consequent over-stimulation or grosser physical injury, and the greater ease with which the group could be caught by predators. The first three of these factors are known in many cases to cause a decreased rate of growth and a decreased rate of reproduction in insects, snails, man and other animals.

Recent work, mainly outside the insect group, indicates that the effect of such aggregations is not always harmful but that they may have real survival value for the majority of individuals due to tonus maintenance, lessening of the rate of change between the individuals and their environment and in the actual modification of their environment in a favorable direction. This last aspect is best illustrated by the fact that a given amount of a poisonous substance is frequently cleared up without ill effect by a group when the same, or even a lower concentration, is fatal for isolated individuals. Such protective relationships are not necessarily restricted to members of the same species and may very well be another one of the integrating factors in the loose organization of biotic communities. The extent of this set of phenomena needs to be established and here the aggregations known to occur at times among otherwise solitary insects appear to furnish favorable material for study. These problems are fundamental in any understanding of the organization of societies of insects, and of other animals and have an obvious economic bearing.

I have said nothing specifically of the problems of the geographic distribution of insects. In essentials the problems involved there have been outlined in the discussion concerning biotic communities. The only real difference is the geographic extent of the community investigated. It is important that such investigations be made as completely and as soon as possible in the habitats not yet dominated by man both for the sake of the knowledge of communities under natural conditions, which is valueable in itself, and for the better understanding of the preservation of the biotic balance as man's influence extends.

Finally this discussion of problems has carefully omitted the most fundamental aspect of the question. The problems outlined appear to me to be of vital importance for immediate solution but you will see on reflection that they are mainly description problems; problems in experimental and quantitative description, to be sure, but chiefly concerned with the question: exactly what is the interrelation between insects and their complete effective environment? In the prosecution of the attack on these problems much incidental light may be thrown on the fascinating and essentially more fundamental problems dealing with the mechanisms by which the environment produces the observed effects. Frequently too, important leads will be discovered which can be followed in a systematic attack on this set of underlying phenomena. But a concerted mass attack upon the problems of the mechanics of the interaction between animals and their environment will be seriously hampered if we do not have a greater accumulation of knowledge than at the present time, concerning the extent and the character of the effects to be explained. Incidentally the immediate problem is infinitely the easier of the two.

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NEEDS IN THE STUDY OF BENEFICIAL INSECTS.

L. O. Howard.

I take it for granted that, in wording this title, the committee had in mind only those insects that are beneficial by preying upon injurious species, and not the honored honey bee or the domestic silkworm or any of the dozen other forms that in one way or another are or have been useful in the arts and industries. Nor do I take it had the committee in mind the insects from which we derive ethical benefits—and indeed these benefits are doubtful. The sluggard will never go to the ant, no matter how many times he has been told to do so since the Holy Bible first took form. Rather, does the ant go for the sluggard!

Naturally our great need in the study of beneficial insects is to gain knowledge that will help us to foster them to the best advantage. If we could domesticate them and use them at will it would be ideal. Possibly with some species a condition approaching this may be brought about. Indeed, it has been brought about in California with *Cryptolaemus montrouzieri*. There, as you know, a stock of Dactylopius is kept up by feeding them on potato sprouts kept in great sheds in such number that an almost unlimited supply of Cryptolaemus is readily furnished to the citrus growers in a more or less commercial way.

Possibly the same situation may be brought about with other enemies of injurious insects, but it is unlikely. We cannot speak positively until we have tried out all the possibilities, and it is in the study of these possibilities that we will find our greatest gaps of knowledge and hence our greatest needs. Just as in the study of injurious insects, it comes right down to the plain statement that we must know everything about them.

First we must have names for them all, and a stable nomenclature. Hence the need for more skilled taxonomists in the parasitic Hymenoptera, in the parasitic Diptera and in the predatory groups of the Coleoptera and Heteroptera.

Second, we must know intimately the biology and ecology of all of the enemies of the principal injurious insects of the whole world, and, after that, of the species of secondary importance.

This should be taken up, of course, species by species; and group generalizations will soon be possible. Some fairly accurate generalizations can be made already, from a study of recorded host relations, but there have been only a few careful studies of the exact life histories of individual species, studies which include details of behavior as well as of the vital processes that must be understood.

The species taken up consecutively will most readily be the parasites or predators of some special host. Little is usually done except to record them by name (and even this is too often incompletely or faultily done). Suppose that such natural enemies of a given host of importance have been studied with care and their biological peculiarities well worked out. Then, after a series of such comprehensive studies, we will have a sound basis on which to begin generalizations as to group biology.

In America we need very greatly workers who are able and willing to go at this biological task. Men and women of any degree of training can help—can do work that will tell. Every careful observation counts, *provided it is recorded in print.* The publication of short notes on individual observations in this direction is greatly to be desired. No one, for example, appreciated the biological importance or rather general occurrence of the feeding of parasitic Hymenoptera at the puncture hole in the host made by the parasite's ovipositor, on reading Paul Marchal's first note of an isolated observation in 1905. *But he recorded it,* and other observers read his note, and year after year in different parts of the world corresponding observations were made with other species, and the habit now assumes an economic interest and a very pronounced importance to the student of evolution.

We need as many men as possible in every part of the world to study the biology of beneficial insects. In America, so far as I know, there are no independent workers at the present time engaged in such investigations; and in the laboratories at Melrose Highlands, at Arlington, at Riverton, New Jersey, at Monroe, Michigan, and at Chatham, Ontario, where the parasites of the gipsy moth and brown-tail moth, of the European corn borer and the Japanese beetle are being intensively studied in the effort to establish them in this country, there seems to be a disposition to withhold publication until many things can be recorded at once.

In France there seems to be a better disposition toward prompt publication, and interesting articles are appearing from time to time from a group of observers including Picard, Lichtenstein, Faure, Trouvelot and Voukassovitch. This should be done in this country. It is a disappointment that the early very important and significant notes published especially by Timberlake and Harry Smith about some of the aspects of their work in the parasite laboratory at Melrose Highlands were not followed up by a rapid series of similar publications from that laboratory. It seems a pity that Harry Smith has not been able to get back to work of this character. It seems a pity that Timberlake has devoted the most of this time in recent years to taxonomic work rather than biologic work for which he is so admirably fitted.

America has at the present time only one institution where work of this kind is being carried on, and that institution, curiously enough, is in France. Thompson and Parker at Hyeres are independently making studies of great interest, and, inspired by Doctor Thompson, a young Frenchman employed in the laboratory, P. Genieys, wrote up some observations which I considered of importance enough to translate into English and which the Annals of the Entomological Society of America thought worth while to publish in their journal.

Doctor Thompson has a philosophical mind and broad training in biology; and it is a pleasure to know that another young American entomologist, also broad-minded and admirably trained, is using part of his time allotted on his fellowship for foreign travel in visiting Thompson at Hyeres and in discussing these questions with him at length. I refer to R. N. Chapman.

We can imagine Doctor Thompson and Doctor Chapman, possibly at the present moment, sitting in the laboratory over there, discussing ardently the broad aspects of natural control, and in all probability discussing this very question—the needs in the study of beneficial insects—and with equal probability bringing out many points which will escape your present speaker. But it goes without saying that they will not argue the point we have just discussed, namely the need of infinitely more work on the intimate biology of parasitic and predatory species. That is self-evident and is basic in any plans for their utilization.

The main trend of practical work with these forms for the past forty years has been their use against imported insect pests. This work has been not only practical, but it has been spectacular and in several instances absolutely dramatic. It has appealed to everybody and has helped to arouse the necessary popular interest in the work of the economic entomologist. Its possibilities have perhaps been exaggerated. Surely it has aroused false hopes as to its ease of accomplishment. I mentioned this in my address at Kansas City last winter in more detail than is necessary at the present time.

Much of this international work is now going on. It is bound to continue. Much time and money has been wasted in the past. Probably much (though not so much) is being wasted now year by year. But this waste is being lessened, and will continue to be lessened more rapidly as we learn more and more about developmental details of individual species and of groups of species. The gaining of such knowledge will not only gradually (very gradually) reduce the necessary amount of foreign travel by experts, but it will bring together a mass of facts that will prevent waste of time in experiment concerning the proper periods and best methods of shipment of parasites from foreign ports and in the best methods of caring for them, rearing them, and liberating them in the regions to which they are sent.

All of this presupposes a very general knowledge by all of the workers about what is going on elsewhere. Again the necessity for the publication of short notes is evident. More than this, no opportunity should be lost which will bring the workers together. To read accounts of how Harry Smith and his fellow workers do certain things in southern California, and of how similar things are done by Smith, King and Allen at Riverton, Jones at Arlington, Atwell and Stearns at Portland; Muir, Fullaway, Swezey and F. X. Williams at Honolulu; Clausen, Gardner and Jaynes in the Orient; Marchal, Vayssiere and Trouvelot at Paris, Thompson and Parker at Hyeres, Berlese and Del Guercio at Florence, Silvestri at Portici, or Webber in Hungary, is all very well; but if they could visit one another from time to time, study individual methods and talk them over, progress would undoubtedly be more rapid.

In this list I have not mentioned the workers at Melrose Highlands nor Babcock's travels in Europe in his study of the ecology of the European corn borer in its native home; but Webber and Muesebeck of

Burgess' laboratory are supposed to return to America from time to time, as has been the case with all of the parasitologists of that laboratory; and at Melrose Highlands they are close enough to Arlington so that the methods in both laboratories are undoubtedly well known to the workers in both.

Caffrey goes from Arlington to Monroe, Michigan and to Chatham, Ontario, from time to time and carries news from Jones to Luginbill and Baird; Silvestri is a world traveler, and Trouvelot is probably coming to America next spring. The problem of L. B. Smith and his associates King and Allen with the natural enemies of the Japanese beetle is rather different in its character. But Harry Smith and Timberlake should at least visit eastern laboratories, and our eastern workers should go out there. Thompson should come to America for a comprehensive trip for his own information and for the good of all of us. And so on, and so on.

A broad statement as to international work which I have made before* may well be repeated here. Since there exist all over the world beneficial insects, many of which can be acclimatized here and some of which undoubtedly will prove of value to American agriculture, carefully planned work should be begun looking towards the increase of our insect population by the addition of as many of these beneficial forms as possible. Results of striking value perhaps could not be expected speedily, but it seems clear that this work should be done. And it will be well for every other country to do the same thing.

Peculiarly open as we have been in this country (and still are to some extent, in spite of the beneficent work of the Federal Horticultural Board) to the introduction, rapid development and spread of foreign insect pests, we have neglected too long the possibilities of native parasites and predators, and I propose the consideration of such possibilities as one of our needs. Not only should we make careful studies of our native species, so as to be in position to help foreign governments which may be threatened with damage by American pests (and this is especially liable to occur to any of the nations lying to the west of the United States), but in our wide-ranging country there are doubtless instances where we can use our own species.

It is surprising how little scientific attention has been given to such possibilities. One's mind goes at once to the large-scale collection of adult Coccinellidæ in the California mountains for distribution among the melon growers of the lowlands, but we have had no scientific analysis of the results of this work although the insects were collected and liberated literally by millions. The work was popular with the growers, and it doubtless brought funds and popular applause to the State Commissioner of Horticulture, but we are in the dark as to the extent to which the results were beneficial or indeed as to whether the work helped at all.

Nevertheless this elaboration on a truly Californian scale of the old European gardener's custom of placing a few ladybirds on a plant badly infested with aphids should be studied scientifically. Plant-lice multiply so rapidly that if we can give their natural enemies an abnormally early or an abnormal numerical start there may be some gain—some advance of the date at which every year the native enemies control the pests.

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*Year Book, U. S. Dept. of Agr., 1916, p. 288.

Of course we must look at things differently when we are working with insects of a different group; expecially when they belong to a different order. Therefore, as bearing upon the question we have just raised, it may not be fair to draw positive deductions from the most interesting experimental work carried on by Webster for the Bureau of Entomology in 1907. This experiment was with the Aphidiine parasites of *Toxoptera graminum,* the so-called green-bug of Texas. Webster, it will be rembered, took two widely separated four-acre fields of winter oats near Manhattan, Kansas. One of these fields was used as a check. Into the other were introduced some millions of parasites sent from Wellington, a point much further south. Careful counts were made from time to time, with the result that the percentage of parasitism in the field into which the millions of parasites had been introduced did not increase quite as rapidly as it did in the check field. It should be mentioned that a somewhat similar experiment was carried on about the same time by S. J. Hunter, who thought that he had good results. Incidentally it may be mentioned that Hunter's claims caused the writer some embarrassment in his hearing before a congressional committee the following winter.

On the other hand, we have another experiment of Webster's with native parasites, carried out the same year (1907). At Lansing, Michigan, and Marion, Pennsylvania, a bad Hessian fly infestation occurred. Examination showed that ninety per cent of the puparia had been parasitized by a species of Polygnotus. A field of wheat near Sharpsburg, Maryland, was infested by the Hessian fly at the same time, and careful examination showed that no parasites were present. On April 8th a large number of parasitized puparia were brought from Marion, Pa., to Sharpsburg and placed in the field. On July 8th the percentage of parasitism was almost one hundred. The writer detailed these two experiments in his address before the Seventh International Zoological Congress at Boston in August, 1907, on "The Recent Progress and Present Conditions of Economic Entomology," and stated "This is the most striking example of the kind that has yet been recorded, and indicates the value of further experimental work in this direction."

It should be stated that later attempts were made to establish this same parasite of the Hessian fly in California, but that they failed.

Occasional experiments of this general nature have been made since, but undoubtedly many opportunities for informative experimentation have been lost. Carriage of parasites for great distances in order to make a good test is not always necessary. Van Dine, for example, down in Cuba, is finding that the Tachinid parasites of the sugar cane borer at times seem localized. Another example of extreme localization was noticed in the city of Washington in 1896 and 1897. Tussock moth caterpillars were very generally defoliating shade trees. In certain sections of the city, however, parasitism by several species reached a very high percentage, whereas less than a mile away it was not evident. In this case the parasites probably would have spread slowly, but the possibility of an easy hastening of the spread by artificial carriage was plainly indicated. Such experimental opportunities as this must not be neglected.

Thus far in this brief paper I have been discursive, perhaps to an extreme, but to those who have followed me must have come the underlying thought that I have realized all along that most of the practical work that has been undertaken with parasites has been of a more or less haphazard character—that we have not known enough of the general principles that govern what we entomologists call parasitic relations, and that an enormous number of specific studies and observations must be made before we can attempt to formulate such general principles.

We cannot predict the success or non-success of any given species carried into a new environment even though one of its preferred hosts occurs there in enormous numbers. We do not know the seasonal history of most of those forms that have multiple hosts. We do not know why a species is abundant in one year and rare the next, except for the occurrence of hyperparasitism or for the fluctuation in numbers of its host or hosts, due possibly to the parasite's own work. In fact, a vast field for workers is open.

Therefore let us encourage as many men as possible to take up the study of parasitic and predatory forms, and let us resolve to let no opportunity pass, however trivial it may seem, to make and to record observations which may help to shed light upon any phase of these strange and important lives.

Then will come the architect who will see that all of the bricks and timbers acquired by these individual workers will be brought together in a harmonious structure satisfactory to the critical mind and of great practical value.

Added note.—Since this paper was written it appears from current publications that several workers in America have realized the situation as I have outlined it and have been doing just the work that I have pointed out as desirable. I may mention especially the recent papers of Dr. Grace H. Griswold .of Cornell, the very interesting study of the parasites of Syrphus flies by Dr. M. Kamal, carried on under Harry Smith at Riverside, and perhaps especially the remarkable papers published in current numbers of the Annals of the Entomological Socirty of America and the Journal of Economic Entomology by Dr. W. V. Balduf of the University of Illinois.

ECONOMIC ENTOMOLOGY.

THE NEEDS IN THE STUDY OF INSECT INJURIES.

E. O. ESSIG,
University of California

The scope of this paper is construed to mean the needs of further study in the field of the actual injuries or losses occasioned by insects and may rightly embrace either animal or plant life. However, the nature of this symposium is such that it is thought best to include only references to plant life and more particularly to crops of commercial importance.

Diagnosis of insect injuries is one of the first principles of economic entomology. To do this correctly and quickly requires a thorough fundamental training and a long rigorous experience: a fundamental training to be able to recognize the insect and its work and experience to sum up the real or estimated amount of injury done or likely to be done, and to prescribe the proper remedy. A deficiency in any one of these may result in great losses, due either to lack of or to misdirected recommendations.

I think that it is not necessary for me to enlarge upon the needs of training and experience as requirements for the recognition of insect pests in all their stages, and the types of injuries caused by each, except to point out that more than scholastic attainments are necessary. I have in mind a case of a caterpillar infesting several thousands of acres of a certain crop which was just getting established in a new district. A large amount of capital was involved, certain huge contracts for planting were ready to be signed, equipment was being prepared on a big scale. This unforseen infestation was like a thunderbolt—everything connected with the venture was paralyzed. The farmers and promoters were thoroughly frightened. These questions were raised: What is it? Is it a new pest? Will it destroy all of the crop? Will it appear every year? Can it be economically controlled? Everyone in the neighborhood gave it the "once over," but no one had ever seen or heard of it before. Then experts were called to the number of at least a dozen from all available sources and with many kinds of experiences. They looked it over. Many views were expressed to the farmers and promoters, but they were for the most part contradictory and unsatisfactory and did not answer the most important questions. In other words they were guesses. However, one finally arrived, who was familiar, not only with this crop, but the other crops of the state. He knew the caterpillar, had known of its presence in the state for ten years, had seen it on many other crops and on the very same crop in the exact neighborhood in small numbers the year before. He had previously reared adults and had them determined at the National Museum and had preserved mounted specimens not only of all stages of the insect, but also examples of the work. This evidence was convincing. The interested parties were informed that the attacks would be spasmodic and infrequent, that they were never ruinous, that the caterpillars could at once be combated at a small cost and the work was begun immediately. Three days had been lost in useless consulation, but in three days more the situation was completely cleared and perfect confidence was restored.

In considering insect injuries and the amount of damage occasioned by them, it is the usual practice to compare the final harvest of an infested crop with that of an idealistic normal crop where no insects are present, without taking into account any of the many factors which may have influenced crop production for that particular year. I know that this is the case because all of the estimates of insect damage are based upon a certain percentage of normal production. These figures are of great value in impressing the uninitiated and in securing needed appropriations, but they mean little in actual farm experience. As an example take the cotton boll weevil. The yearly estimated losses due to the ravages of this insect would support the government and should at least cause a cotton grower to pause before planting another crop, and yet we find that during the past year so much cotton was produced that it became a drug on the market; that in order to control this insect, cultural methods have been adopted which results in a far greater production of cotton under weevil conditions than where weevil does not exist; that on the whole the weevil has been a blessing to the cotton industry. Similar statements have been made concerning the alfalfa weevil in some parts of the Great Basin. I am not vouching for the authenticity of any of these statements, but they indicate that we have not succeeded in presenting the facts; that a different basis for estimating insect injuries is needed.

As I look at economic entomology in relation to crop production it appears to me that the only thing that counts in actual field practice is the *amount of the infested crop saved above the cost of control.* If this does not exceed the cost of control it is not warranted and becomes a useless waste of money and energy. An apparent exception, however, which bears on the problem, is a case where the cost of control measures may not be warranted by the amount saved that year, but may be thoroughly justified by preventing a reoccurance of the pest the following year. It is therefore necessary for the economic entomologist to be familiar with crop production and farm practices in order to make a proper estimate of such injuries. For instance an estimate of injury due to the codling moth made before thinning, might be greatly under or over estimated if the entomologist did not take into consideration, not only the actual process of thinning, but also the disposal of the infested apples removed from the trees. The value of the crop is also often entirely overlooked. I recall recommendations made to control the larvæ of the pasture crane fly, amounting to only $3.00 per acre, which seemed small enough, but was out of the question when the pasture was only worth $2.50 per acre. Such cases may be enumerated at length.

Many ingenious methods have been suggested as a means of securing uniformity in estimating injuries and losses occasioned by insects, but these usually fall short of practical application because of the many uncontrollable factors with which we have to deal. Laboratory tests and field tests on a small scale are valuable in determining essential points, but they cannot be relied upon until fully tested and found satisfactory under practical field conditions.

In determining the amount of injury as a basis of recommendations for pest control it is necessary to know how much loss of foliage or fruit is permissible without actually interferring with the production of a satisfactory crop. Thus it may often be a distinct advantage to destroy a certain percentage of both fruit and foilage and in other cases, while such destruction may not be desirable, yet the actual damage to the tree may be so negligible as not to warrant control. In contrast to this type of injury the crop may be so severely injured that the cost of control measures would only be adding to the misfortune, except as already pointed out where a reoccurring pest may be eliminated for the next year. Between these two extremes, that is somewhere from a minimum of 15% or 20% to a maximum of 70% or 75% injury, control is usually always warranted and it is the ability to recognize this point that is most needed.

One of the outstanding needs in economic entomology is a study of the injuries caused by fungous and bacterial organisms carried by insects. Because this field lies within the domain of entomology and plant pathology it has been neglected by both. However, since the discovery that certain mosaics, potato tip burn, curly top of sugar beets and other diseases are transmitted by insects this field is attracting many workers so that some of the obscure injuries to plants which have puzzled entomologists are becoming known. One thing is sure: unless we know what is causing the injury we cannot intelligently prescribe the remedy.

In closing I may say that I do not believe that uniform rules can ever be formulated to cover the needs so imperfectly discussed in this paper. Training, skill, judgment and experience are not reduciable to formulæ but they can all be cultivated and increased.

In summing up I should like to emphasize the following points:

1. The need of wide training on the part of the economic entomologist, particularly in agricultural botany, so that he may better understand, not only the types of injuries, but the lasting effect of the same on the individual host plants and on a crop.
2. The need of detailed studies or observations of the feeding habits of the various stages of insects in order to be able to properly diagnose the case at hand.
3. The need of the constant varification of data to reach practical conclusions.
4. The need of a careful study of the complete situation before reports or recommendations are made. The need of sane conservatism in estimating losses due to insects—these losses are sufficiently great to require no exaggerations.
5. The need of recognizing the importance of conserving the farmers income by not recommending measures unless they are fully

warranted as well as to emphatically urge control when by such means the crop may be saved from insect depredations.

6. The need for further studies by entomologists, plant pathologists plant physiologists, and bacteriologists to broaden our exact knowledge as to *how* insects *injure* plants.

7. The study of the past history of insect pests to properly estimate the probable results of present attacks.

NEEDS IN THE STUDY OF CONTROL MEASURES.

W. P. Flint.

It often seems that we have advanced only far enough in our work of insect control so we begin to realize how ignorant we are. There is certainly need for further studies in practically all lines of insect control. It is obviously impossible to say what studies are most needed at this time. The control which is satisfactory today may be of little value in a few years, owing to changing conditions, or possibly to adaptations of the insect which has rendered it more difficult to kill. At the last Pittsburgh meeting of the Association of Economic Entomologists, Professor O'Kane presented a review of control measures, rating the methods according to their efficiency in combating different species of insects. The standing of the control measures for the insects listed being based on the replies received to a questionnaire sent out to a large number of entomologists. It is quite certain that if the same paper was presented today and the ratings of control based on the opinions of the same entomologists, that the degree of effectiveness given for the control measures would vary considerably from that given in 1918, and that the rating of control for certain insects would not be as high as it was eight years ago. This shows that in all our work on insect control, it is necessary to constantly study the results being obtained by control measures which have been considered satisfactory. Such studies are necessary to be sure that an unfortunate situation does not develop where the measures being advocated have ceased to be as effective as formerly, and the insect pest which we are trying to control be permitted to increase to a point where heavy damage may occur. A very good example of just such a condition is afforded in the increase in San Jose scale in the central states during the years of 1918 to 1922. In other words, it is not sufficient that we work out the facts concerning the life history and habits of an insect and develop an effective control, but we must continue to study the insect and the results of the control.

Further studies are badly needed in what we may term, insect behavior, after the life history of an insect has been worked out for a certain region with a reasonable degree of exactness. We are badly in need of further and more intensive studies on the behavior of the insect, or as we may style them, detailed ecological studies of the response of the insect to all factors of its environment, in that region and for as many different localities as possible where it is destructive, and where it occurs, but does not cause damage. Dr. C. H. Townsend in a recent paper in Ecology,* has outlined very clearly some of the work needed along this line. Such studies are necessary for all of the more commonly injurious species of insects. We can not hope to reach the highest degree of efficiency in insect control until we have a more definite knowledge of the exact effect on the insect, and the control measures of such factors as heat, sunlight, rainfall, wind movement, humidity, abundance or lack of favorite food, and many others. It is necessary that we should plan such studies to extend over a period of years, as immediate results of any value can not be expected. In most cases, the entomologist has felt that pressure for immediate results was such that it was not possible for him to carry such studies over any very long period of time, and in many cases, the demand for immediate means of control for a number of different insects is impressed so strongly upon the entomological workers that while the need of a long time program is recognized, it has been impossible to carry it out. Perhaps we can gain something from studying the methods used by the agronomists, where their experiments are often laid out with no idea of definite results for ten or more years.

HIBERNATION.

Another line along which control studies are badly needed is that of the actual effect of crop rotation on insects. A brief review of the recommendations given in several of the leading books on economic entomology shows that crop rotation is recommended as a control measure for approximately 60% of our destructive forage and field crop insects. How much actual data can be presented showing definitely the effect of crop rotation on increasing or decreasing the number of insects in a given field, or a given agricultural area. A rotation that will place a legume crop in fields heavily infested with an insect that feeds exclusively on grasses, is certainly of value, but how much information do we have on what actually occurs in such fields and as to the exact effect of a good system of rotation, or one that is generally recommended by entomologists on the insect population of a field, a farm, or a locality where such a rotation is generally followed. Studies along this line are difficult to make, and to be of any value, must be carried through a long period. They are certainly badly needed. Much the same may be said regarding the need of studies of the effect of cultural practices on insects. That certain cultural practices will have an effect in reducing the numbers of insects in the field we know, and we have some definite information on the actual effect of different practices on insect populations. No one familiar with the facts in the case, and the meager amount of data which we have to present to back up our recommendations would say that there is not a very decided need for further study along this line, and the accumulation of much more definite information than is now available on the effect of cultural practices on insects under the varying conditions which may occur in the same region during different seasons.

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* Ecology Vol. 2, page 326-337.

AGRONOMY RELATIONS.

Another line of needed study which is now being taken up, is on the tropisms of insects, of these, studies of the Chemotropisms are of special importance. We have been going on year after year applying sprays for insects that are leaf feeders, and have paid but very little attention, as to whether or not these applications were repellent, or attractive to the insects which we were trying to control, at least so long as they were not so strongly repellent as to actually prevent feeding. The relatively small amount of work that has been done in actually testing the response of insects to different chemical stimuli, producing different odors and flavors, has shown that there is an ample field for intensive studies along this line, and that it is reasonable to suppose that we can greatly improve the efficiency of many of our poison sprays if they are prepared in such a way as to make them really attractive to the insects we are trying to combat. Perhaps the best example of what may be done along this line, is the recent work carried out at the Japanese Beetle Laboratory, where it has been found possible to actually attract the beetles for a considerable distance to certain shrubs or trees that have been sprayed with a chemical giving off an odor attractive to them, and then destroy them by the use of a contact insecticide. Studies along this same line may make it possible for us to give our main attention in the future to spraying only certain rows of trees in our orchards and gain a better protection from some of the orchard insects than is the case with the methods we are following at the present.

These are only a few of the many lines along which further study in insect control is greatly needed, and some of the things which must be done if we are really to keep our science abreast of the developments in other lines. For the past ten or more years, insects as a whole, have probably been gaining rather than losing in their fight with man. This fact, if we admit that it is true, brings out sharply the need for further studies on insect control.

SUMMARY.

E. F. Phillips.

It pays occasionly to take stock to see what has been accomplished. In the present discussion we have gone beyond this by outlining the work needed for a more effective attack on the unknown. Naturally each speaker has emphasized the needs in his own field, yet each one has had it in mind that every other aspect of Entomology is equally in need of further work if the Science is to progress along proper lines. Each of us can readily think of many more needed investigations. It is impossible to summarize this discussion, in a narrow sense of the word, and all that one can do is to attempt to outline the general needs in the light of what has been said, while running the risk of becoming philosophical or of expressing platitudes.

Every one must be impressed with the need of more and better work and of more and better workers. A member of this Society recently compared present progress in Entomology with that of an attempt to tunnel the continental divide with teaspoons, and while the situation is perhaps better than his simile would suggest, there are so many things that we wish to know that somtimes progress seems rather slow. Each newly discovered fact increases the number of things which we wish to know. Instead of feeling hopeless, we should recognize it as a duty and privilege whenever and wherever possible to encourage the teaching of Entomology, in the hope that among those thus taught there may be some who have that peculiar type of mind needed to help extend the boundaries of our knowledge in some of the needed directions.

Future investigations in Entomology will include more than a study of insects. Statistical methods, Chemistry, Physics and other scientific facts and methods must be used to enable us to cover the field even now presented. I was especially impressed by Doctor Kennedy's suggestion to apply zonal studies to control measures in Economic Entomology. If I may refer for comparison to a field not previously discussed, in Apiculture we have for some time been studying the relation of soils to the suitability of a region for commercial beekeeping. When some years ago I asked the Federal Bureau of Soils for information, I was told that I was one of the very few workers in other fields who was attempting to utilize soil surveys. Vegetation types often follow soil types, and in many instances the physiological condition of plants is clearly influenced by soil composition and physical character, so that we can not afford to neglect such lines of biological investigation.

A most vital problem, after all, is the proper teaching of Entomology. In presenting the subject to those who will be the investigators of the future, the teaching can no longer be confined to entomological studies proper, if we expect them to become the type of workers which is demanded. This can be brought out best by reviewing the evolution of Entomology. The first step was obviously the descriptive one, Taxonomy, and at first this consisted largely of collecting and classifying adult insects, not the future type of Taxonomy which has today been presented. Next came the second descriptive stage, Morphology, but again not the future type. During the descriptive stage of biological science there developed the great philosophical concept, Evolution. Gradually insects came to be looked upon more as living units in a community of life rather than dead adult specimens to be pinned or dissected, and this brought in Physiology, Ecology, Parasitology, Embryology and other lines of investigation which deal with behavior, life processes and inter-relationships. These later studies make it necessary that the student call to his service Chemistry, Physics, Meteorology and more recently allied lines of biological investigation aside from Entomology itself, such as plant distribution, morphology and physiology, soils as a living entity, comparative psychology and the like. In short, progress has been brought about by widening the field of Entomology to include almost the whole gamut of sciences, while at the same time we have narrowed it by each selecting a small corner in which to work. It is interesting in passing to note that the philosophic phases of the subject attract less and less attention as the horizon widens, since finally all must realize the futility of attempting to grasp the meaning of the whole. Detailed behavior studies indicate that insect species vary greatly in their adaptability to new environmental conditions. Most of them appear to have little adaptability because of instinctive limitations or because of morphological specialization and consequent specialization in physiological function. We dare not make analogies between even closely related species but must conduct investigations in behavior and physiology for each species. This outline of the evolution of Entomology indicates the need of broad training for the future entomologists, if they are to conduct the investigations which have previously been outlined.

The pressure for results along economic lines has often resulted in enlisting in the work, men who do not have adequate training to undertake investigational work. In many cases it is necessary that control measures be advised before there is time to undertake investigations along physiological, ecological and other biological lines. One can not in the least blame the public for demanding remedies, nor can one justly blame the entomologist for giving out the best possible advice, yet it is extremely unfortunate if the advice bears unwarranted earmarks of finality. The advice may at times contribute to results almost as bad as the damage of the pest itself, unless every phase of the subject is given full consideration, as witness the difficulty this year in the Northwest with arsenical residues.

Today it is not possible for any one entomologist thoroughly to know more than a small part of the field, and this is becoming more and more true each year. This indicates that workers of the future must be still more highly trained and highly specialized, but this brings up a serious problem. The person who too soon specializes to to high a degree misses a considerable part of the fun of his work, for his outlook is too rapidly narrowed, so that at no time can he stand upon the mountain top and view the whole field, even though through a haze.

The old workers in Evolution made much of the dictum that Ontogeny recapitulates Phylogeny, and it may be that the best training for the young and enthusiastic entomologist is to lead him through much the same stages through which the Science has passed in its evolution, thus giving him for a while the pleasure of the philosophic aspects of the subject. In other words, it may not be wise to lead him too early into specialization, but rather to allow him for a time to enjoy himself by being in a sense an old time naturalist and philosopher. If he begins early enough, this entails no serious loss of time. Progressively, but of necessity rather rapidly, he can be led into a narrower field, yet at the same time a broadening one, by giving him the fundamentals of those parts of Chemistry, Physics and other branches of Biology itself on which he must depend. The serious danger here, from the standpoint of the teacher, is in knowing into what allied lines of work each student should be led, for he can not enter them all. There is danger that each teacher will emphasize too greatly the requirements of his own limited field and that the beginning student may not have a free opportunity to choose for himself. Naturally no one institution can offer all the work which even now has a bearing on entomological investigation, and this will doubtless lead still more to specialization between the institutions themselves, which may be a bit rough on the students, unless in some way they may be able to go from one institution to another freely. The broad training needed for the future will not only create interest on the part of the student but will indicate to him that Entomology is something more than the squirting or dusting of arsenicals on the tails of insects. In fact this is scarcely Entomology at all, any more than horse-shoeing is animal husbandry. Applied courses given too early in the training and experience of the student should and do give him a biased view of the Science and are apt to repel him from further work.

There are fads and fashions in science as in clothes, and whenever a new means of investigation comes to light, there is danger that the value of a single factor may be over-estimated. This Doctor Allee has pointed out with mention of the recent work on hydrogen-ion concentration. In the whole field of Zoology, one can not fail to recognize the waves of subjects and methods which have passed, and lines of work formerly much stressed are now quite obsolete. Day before yesterday it was statistical method, yesterday it was hydrogen-ion concentration, today it is something else and tomorrow the style will again change. There is much to be said for the worker who reads and uses the results of such fashionable work but who steadfastly refuses to be carried away.

When we are confronted by a situation such as this, there almost invariably arises some supreme egotist who thinks that he is better able than anyong else to organize the work of the future and who advocates a strict coordination of the work along those lines which appeal especially to him. The investigator is an individualist and must be allowed to go his own gait, except for such wise guidance as may be available. In only a limited way is detailed direction tolerable, and this occurs when the public, through its legislative bodies, determines that a certain line of work is needed for the benefit of the public itself. In that event, the executive charged with the conduct of the work must see that those employed for the work shall confine their attention largely to the work outlined in the appropriation, but even in such cases a considerable degree of freedom has given the best results. For some years I worked under the direction of the man whose administration has largely made Economic Entomology what it today is. Many think that they know better than the Chief how the Bureau of Entomology should be administered and some designate as administrative weakness the freedom which Doctor Howard allows. Those who know agree that this so-called weakness is the one thing which has done most to make his administration effective.

An even more wholesome method of coordinating work is that observed when a leader in Entomology, such as a competent teacher, gathers about him a group of cooperating workers, all interested in related subjects but each with his own small problem. In this case the cooperation is voluntary, done because of an interest in the subject and under the direction of a leader who has a broad view of the meaning of the individual investigations and of the selected field as a whole. In this case there is not even that administrative pressure necessary in economic investigations, and the success of a strong leader is proof of the desirability of just as little administration and organization as possible. We hear much of the benefits of cooperation, in scientific work as elsewhere, but it is one of the oddities of the race that we cooperate only when there is no other course available or when it is proven that each of us will receive personal and tangible benefits. This calls for wise leadership, not dictatorial methods.

In short, the previous papers indicate that Entomology needs something comparable to an old fashioned revival of religion, without, however, any misrepresentation of values or of the opportunities for future employment, not Rotarianism but the creation or revival of interest in students. For leadership in this work, we need men of broad vision, capable of seeing the relationships between the many lines of work already conducted, capable of planning new fields for investigation and with courage to enter these fields, and also capable of coordinating investigations and of enlisting voluntary cooperation, but Entomology has not come to such a pass that it needs a Mussolini to direct it. Let us hope that entomological work may always be conducted along democratic lines of free and unrestricted cooperation. As Doctor Allee has said regarding Ecology, it is hard to know where to begin and what to defer resolutely for the present, but this decision and others must be left largely to the judgment of the individual and to the voluntary following of wise leadership. After all, leadership is the greatest need in Entomology, if I interpret the previous papers properly, and with wise and constructive leadership the needed investigations which have been pointed out by former speakers will follow as a matter of course.

THE BIONOMICS OF ANASTATUS ALBITARSIS ASHM., PARASITIC IN THE EGGS OF DICTYOPLOCA JAPONICA MOORE (HYMEN.).

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Introductory.

During the late winter months of 1920 the writer observed numerous large, conspicuous egg-masses of the Saturniid moth *Dictyoploca* (*Caligula*) *japonica* Moore upon the trunks and larger branches of various deciduous forest trees in the vicinity of Yokohama and Tokyo, Japan, and further observations showed it to be a pest of *Prunus* spp. as well as chestnut and camphor. A number of these egg-clusters were collected at the time and set aside for parasite rearings, with the result that a considerable number of a Eupelmid, later determined by Mr. A. B. Gahan of the U. S. Bureau of Entomology as *Anastatus albitarsis* Ashm., emerged, accompanied by a smaller number of an undetermined Trichogrammid.

In the following season it was noted that the larvæ of this moth were inflicting extensive injury to deciduous forest and shade trees, at times amounting to complete defoliation, and this condition persisted during the five years the species was under observation. The life cycle covers a period of one year, with the winter passed in the egg stage upon the trunks and branches of the various host plants. The eggs hatch in late April or early May and maturity is reached late in the summer, the eggs being deposited during the latter part of September and in October.

Observations were made in four localities, namely: Nagasaki in Kyushiu, the southern island, Yokohama and Tokyo in Honshu, and Sapporo in Hokkaido, the northern island, thus covering in latitude a range of approximately 750 miles. The field parasitism of the eggs by *Anastatus* for the four localities is given in Table I, and ranges in effectiveness from 16.3 per cent at Sapporo in 1921 to 34.3 per cent at Tokyo in 1920. A total of 23,015 eggs were collected and set aside for emergence, and from this number 5,983 adults of *A. albitarsis* were reared, a percentage of 26.0 for all localities during the years 1920 to 1922 inclusive. The host egg-masses often comprised one hundred or more eggs, and in some instances, particularly those collected in the Botanical Garden at Tokyo, the parasitism approached one hundred per cent for individual clusters.

The observations on the life history and habits of this species were undertaken in connection with a comparative study of the biology of the various groups of parasitic Hymenoptera, and the immature forms, particularly the first larval stage, were found to differ to a considerable extent from those known among other species of the same genus and related groups.

TABLE I.

Anastatus albitarsis Ashm.—Field Parasitism.

1920	Yokohama	Tokyo	Nagasaki
Number of eggs collected	2,500	4,000	2,350
Number of parasites emerged	421	1,373	748
Per cent parasitized	16.8	34.3	31.8
1921	Yokohama	Tokyo	Sapporo
Number of eggs collected	1,560	3,400	2,980
Number of parasites emerged	372	1,069	487
Per cent parasitized	23.8	31.4	16.3
1922	Yokohama	Nagasaki	Sapporo
Number of eggs collected	1,750	1,275	3,200
Number of parasites emerged	502	397	614
Per cent parasitized	28.7	31.1	19.2

LIFE HISTORY AND HABITS.

Oviposition.—The female first examines the host egg leisurely with the antennæ, this often extending in time over five minutes or more, and if satisfied she then takes position on top of it and brings the ovipositor tip forward in a vertical position and in contact with the egg. The tip of the abdomen assists in this process and is then raised to the normal position. The piercing of the shell of the egg requires approximately fifteen to twenty minutes, and during this time the only movement of the body is a slight rhythmic raising and lowering of the abdomen. After penetration has been finally effected the ovipositor is frequently inserted its full length and withdrawn, and when fully inserted the female rocks forwards and backwards and also somewhat to the side, apparently examining the interior of the egg with the tip of the ovipositor. She may turn completely about several times during this period, using the fixed ovipositor as an axis. At times she may withdraw it entirely, later returning to complete the process at the same puncture hole. Finally the ovipositor is thrust to its full length and the egg deposited. It is free-floating in the fluids of the host egg. The entire process of oviposition covers a period of thirty to sixty minutes. Frequently the female feeds upon the fluids exuded at the puncture hole. At times the puncture hole in a

TABLE II.

Anastatus albitarsis Ashm.—Oviposition Records, 1922.

Feb.	A	B	C	D	E	F	G	H	I	J
6	1	0	4	1	3	0	4	6	2	3
7	6	3	5	3	5	1	3	3	2	2
8	3	7	5	6	6	5	4	4	5	6
9	5	4	5	2	5	4	6	4	3	5
10	4	3	2	5	5	5	5	6	5	2
11	6	5	7	0	4	2	4	6	5	7
12	2	6	4	8	6	5	4	2	4	4
13	5	5	4	3	6	3	4	5	3	5
14	4	5	6	3	5	6	5	0	6	3
15	7	4	3	3	5	2	3	4	6	4
16	1	3	6	5	5	6	2	3	4	6
17	3	2	2	5	4	3	5	3	5	2
18	5	5	4	2	1	4	1	6	1	6
19	0	4	3	2	D	4	D	4	5	4
20	4	4	4	5	......	3	......	4	3	3
21	6	4	D	5	......	2	......	2	0	D
22	1	D	......	D	......	D	......	1	2	......
23	D	......	......	......	......	......	......	D	D	......
Total eggs	63	64	64	58	60	55	50	63	61	62
Av. per day	3.7	4.3	4.3	3.6	4.6	3.7	3.8	3.7	3.6	4.1
Duration, days	17	15	15	16	13	15	13	17	17	15

D—Female dead.

Average of 10 females..60 eggs
Average number of eggs per day............................ 3.9
Average duration of oviposition period....................15.3 days

parasitized egg may be detected by the presence of the hardened drop of egg fluid which has exuded following oviposition.

The probing with the ovipositor, mentioned above, is apparently for the purpose of determining the stage of development reached by the embryo or the presence of another parasite larva therein. It was not possible to induce oviposition into eggs containing fully developed embryos or parasite larvæ in the advanced stages.

To determine the rate and duration of oviposition a series of twenty-five fertilized females which had been reared out from field-collected material was used for this experiment. The host eggs used were those collected in the field shortly after having been laid in the late summer, and kept in cold storage until needed, so that embryonic development had progressed but little. Ten eggs were provided for each female *Anastatus* per day, and these were later dissected and the eggs contained in them counted. The results for the ten best females are given in Table II. These ten were unusually uniform both in respect to the duration of the oviposition period and in the number of eggs deposited, the former ranging from 13 to 17 days, with an average of 15.3 days, and the latter from 50 to 64, with an average of 60 eggs. From the table it will be seen that the maximum number of eggs laid by a single female in one day was 8, while the average for the entire series was 3.9 eggs. While these experiments were conducted under laboratory conditions it is believed that the results follow quite closely the normal development in the field.

The Larval Stages.—The embryo develops within the egg with its head at the posterior end near the base of the pedicel (See Fig. 2), and may be clearly distinguished through the chorion. The bifurcate process at the caudal end is closely appressed to the body ventrally. Emergence is effected by a break in the chorion at the posterior end near the base of the pedicel in the same manner as described by Phillips and Poos (7) in the case of *Eupelmus allynii.* The larva now lies free in the semi-fluid contents of the host egg, and by means of the ventral rows of spines on the body segments, supplemented by the caudal process, is able to move about in the surrounding fluids. A regular flexing and reflexing of the body permits of the utilization of these structures for that purpose.

The second-stage larva lacks these spines and the long caudal process and is consequently largely incapable of movement, but lies free in the egg fluids. The third stage effects complete consumption of the egg contents before maturity is reached. In the resting condition both ends of the larva are curved ventrally to conform to the shape of the shell within which it is enclosed, the head being always at the posterior end of the host egg. Shortly before pupation the meconium is cast, this being observable as a dark-green, viscid mass placed in the mid-ventral curve of the body. The larva is now bright yellow in color as contrasted with the former mottled green. Shortly before the final moult the developing eyes of the pupa can be seen beneath the derm of the first thoracic segment. The larval skin breaks in a longitudinal line over the head and first two thoracic segments and is forced back over the body, remaining as an irregular ribbon attached to the tip of the abdomen of the pupa.

The Pupal Stage.—The pupa is of the usual form, with both the head and abdomen bent ventrally to fit the outline of the space within which it is confined. The males may be distinguished by the longer antennal sheaths. The only distinctive feature about this pupa is the three prongs superimposed over the ocelli of the developing adult (See Fig. 9). The median prong is longest and directed forwards, while the remaining two point backwards. These prongs may be for the purpose of preventing the head from coming in contact with the shell which encloses the parasite, and are similar to structures found upon the pupæ of many Pompilidæ which are contained in cocoons in the soil. In the latter case their function is obvious, and they are supplemented by similar structures on the thorax and abdomen. Thus moisture penetrating the cocoon does not come in direct contact with the body.

Emergence is effected by the cutting of a hole of rather irregular outline through the upper end of the egg-shell, though occasionally at one side. This hole is not readily distinguishable from that made by the host larva in hatching, though usually slightly smaller.

THE LIFE CYCLE.

The cycle of *A. albitarsis* usually covers one full year, the adults emerging during May shortly after the hatching of the host eggs. The males precede the females by an average of three days, and the two sexes appear in numbers in the ratio of 1 to 1.4, the females predominating. Mating takes place almost immediately. In case of parthenogenetic reproduction the progeny are all males. The females are very active and capable of jumping great distances; in fact, this rather than flight is their chief mode of movement from place to place. In jumping the abdomen is bent sharply backwards over the thorax, and in alighting the female frequently tumbles about somewhat before gaining a foothold. This corresponds quite closely to the account given by Riley of (*Eupelmus*) *Anastatus mirabilis* (Walsh and Riley), "the back-rolling wonder."

The length of life of the adult female is from five to six months, extending from May to October or November, at which time freshly deposited host eggs are available for oviposition. The males die shortly after mating. No intermediate host is known.

The egg stage covers a period of three to five days, dependent upon temperature conditions, and the mature larval stage is reached within one month. It is in this condition that hibernation takes place. The pupal stage is short, extending over about two weeks.

While one generation per year is the normal condition, yet there is evidence to show that a partial second occurs in the infertile eggs of the same host generation in the spring, and this was demonstrated experimentally in the laboratory. *A. albitarsis* is a true egg parasite, as has already been pointed out, and develops free-floating in the egg fluids rather than in the body of the developing embryo. Laboratory tests to determine to what extent development is possible in eggs of various stages of maturity showed that oviposition and normal development took place only so long as the egg cavity surrounding the growing embryo was filled with fluid. The egg was never deposited within the embryo. This same condition was found to hold true with respect to several other species of the same genus which were studied.

DESCRIPTION OF IMMATURE FORMS.

The Egg (Fig. 2). Total length, 0.68 mm., the main body being 0.5 mm. in length and 0.11 mm. in width, slightly curved as shown in the figure, and widest towards the posterior end. At the anterior end is a minute tubercle, while the opposite end bears a large, prominent pedicel 0.18 mm. in length, which is firm and turgid at all stages of development. The chorion is heavy, firm and without sculpturing. Color white, and granular when viewed by transmitted light. The mature ovarian egg is of similar size and form.

The First-Stage Larva (Figs. 3 and 4). Length to tip of caudal process, 1.2 mm., width, 0.2 mm.; body form as shown in the figures, the segments very distinct and diminishing in diameter caudad.

Head robust, thimble-shaped, heavily chitinized, and slightly brownish in color; one pair of short setæ situated ventrally and near the middle; the buccal area rather large, with the mandibles simple and dark in color.

Body segments thirteen in number, distinct, and approximately equal in length except the last, which is much extended into a heavily chitinized, bifurcate process, the points of which are very sharp. The "prongs" of this process are sharply curved at the base and lie at right angles to the body axis. Between the base of these and the anterior ventral margin of the segment is a pair of short, stout protuberances. The second and third thoracic segments and the first seven of the abdomen bear ventrally near the anterior margin a row of twelve to fifteen long, heavy spines, those on the second thoracic segment being very long, and diminishing in length on the successive segments. The spines on the median line are longest, the others diminishing in length laterad. Neither the bifurcate structure nor the two smaller supplementary processes bear spines or setæ of any sort. Body color white, with the digestive tract distinctly visible through the derm.

The tracheal system comprises four pairs of open spiracles, these being situated on the second thoracic and the first three abdominal segments respectively, and the lateral trunks are connected by posterior and anterior commissures.

The Second-Stage Larva (Fig. 5). Head similar in form to that of the first stage but relatively much smaller, with one pair of setæ situated ventrally.

Body segments thirteen in number, with the first abdominal segment widest, and diminishing anteriorly and posteriorly. The thoracic and abdominal segments about equal in length and distinct, the last segment bifurcate, but lacking the heavily chitinized prongs of the preceding stage. Three pairs of cuticular spines on each of the thoracic segments and two on each abdominal segment except the last.

Tracheal system with eight pairs of open spiracles.

The Third-Stage Larva (Fig. 9). Length extended, 2.5 mm., and width, 1.0 mm. Body distinctly segmented and robust. Color a mottled green and white, the green due to the contents of the digestive tract showing through the derm and the white to the numerous irregularly shaped fat bodies lying near the surface. The green is most noticeable in the median abdominal area.

The head (Fig. 7) is small and somewhat retracted, with two prominent tubercles representing the antennæ situated on the transverse median line. Four pairs of sensory setæ are present, one situated slightly mesad and above the antennæ, the second slightly laterad and above, the third directly laterad and the fourth laterad of the buccal aperture. Two pairs of heavy greenish lines extend from the posterior margin of the head nearly to the antennæ, those of each pair uniting and again separating just before reaching the antennæ. The latero-ventral portions of the head are greenish-black in color. The mandibles are simple, sharp, and black in color distally.

The thirteen body segments are distinct and of nearly equal length except the last, which is shorter. The first thoracic segment bears two pairs of cuticular spines, and the second and third three, while the abdominal segments from the first to the seventh bear two. The derm of the lateral margins of the second and third thoracic segments, and dorsally on the first seven segments of the abdomen as well, with fine, irregularly linear granulations, being slightly darkened in color on the thoracic segments and in the spiracular areas.

The tracheal system comprises nine pairs of open spiracles situated on the second and third thoracic and the first seven abdominal segments.

The Pupa (Fig. 8). Length, 1.4 mm., with the head appressed ventrally and the abdomen curved likewise, the central body axis thus being practically a semicircle. Head with three fleshy prongs situated over the developing ocelli (Fig. 9), the median one directed forwards and the two laterals pointing caudad. The color ranges from white in the newly transformed individuals to black just prior to emergence, the iridescent reflections from the thorax being then visible through the pupal integument.

THE PRIMARY LARVA OF A. ALBITARSIS COMPARED WITH OTHERS.

The features in which the primary larva of *A. albitarsis* differs from that of other Chalcidoidea are the transverse rows of long, heavy spines ventrally on certain of the body segments and the long, heavily chitinized bifurcate process terminating the caudal segment. In most of the forms of caudate larvæ among the parasitic Hymenoptera the last segment is prolonged into a large fleshy process, which is unquestionably respiratory in function. Typical of this form are the Braconidæ, some Ichneumonidæ, certain Aphelinidæ, Chalcididæ, various Encyrtids, etc. The bifurcate appendage of *A. albitarsis* is similar in all essential respects to that found upon the primary larvæ of various Proctotrypoid egg parasites (Scelionidæ), and in neither case can its function be considered as respiratory. It is worthy of note that many of the most remarkable morphological modifications among the primary larvæ of the parasitic Hymenoptera are found among those parasitic within the eggs of other insect species. It is probable that the bifurcate appendage mentioned was originally ambulatory in function and still serves in this way to a limited extent, though in a fluid medium rather than upon an external surface.

In a recent paper Parker (5) discusses at length the post-embryonic development of the Chalcidoid Hymenoptera, and has classified the primary larvæ morphologically into seven groups. *Anastatus* was not figured therein, but slightly later Parker and Thompson (6) published an account of the primary larva of *Anastatus* sp. which they consider to be a transitional form between the free-living endophagous larvæ, typified by *Ceraptorocerus mirabilis* Westw., and the ectophagous larvæ of the group including *Leucospis*, *Eupelmus*, *Eurytoma*, etc. The larva described bears numerous cuticular spines, though not localized ventrally, and a short bifurcate caudal process. The larva of *A. albitarsis* is of a more primitive type than that described by Parker and Thompson. All of the caudate forms discussed, in which the process is bifurcate, have these processes very short, and in none of them is there any indication that they have a respiratory function. It is possible that among the Hymenoptera the two caudate forms are of entirely different origin, the simple being respiratory and the bifurcate ambulatory. It is noteworthy that in certain widely separated groups of parasitic insects, the primary larvæ of which are under the necessity of searching for their hosts, nearly all bear on the caudal segment a pair of strong setæ of greater or less length. As typical of these may be cited the Perilampidæ and Eucharidæ among the Hymenoptera and the Acroceridæ, Bombylidæ and Dexiidæ among the Diptera.

The hypothesis presented by Parker and Thompson that *Anastatus* is a form which recently has adopted the habit of endophagous parasitism and is now undergoing the changes incident to such transformation of habit may be considered as strengthened by the further evidence adduced in the case of *A. albitarsis.*

HOST RELATIONSHIPS OF THE GENUS ANASTATUS.

A review of the published records of the hosts of this genus reveals it to be confined very largely to the eggs of four orders of insects, namely: Lepidoptera (*Nymphalidæ*, *Lymantriidæ*, *Lasiocampidæ*, and *Saturniidæ*), Orthoptera (*Blattidæ*, *Mantidæ*, *Acrididæ* and *Locustidæ*), Hemiptera (*Pentatomidæ* and *Coreidæ*) and in a single instance from a Neuropteron (*Torbia viridissima*). An exception to this *A. pipunculi* Perkins, recorded as being parasitic in the sacs of the Dipteron *Pipunculus cinerascens* and also in those of *Paradryinus* sp., belonging to the hymenopterous family *Dryinidæ*, both parasitic upon leaf-hoppers in Australia. In Ceylon *A. tachardiæ* How. is reported as parasitic upon the lac insect (*Tachardia albizziæ*), but in view of our knowledge of the habits of the genus the record must at present be considered as questionable. The doubtful record of *A. aureicorpus* Girault from a single Syrphid puparium in Texas is almost certainly erroneous.

Aside from lepidoterous eggs the writer has reared species of this genus most commonly from the eggs of *Pentatomidæ* and *Coreidæ*, and it is probable that the eggs of other families of the order, of which the species have similar habits and are of sufficient size, are also attacked.

LITERATURE ON THE BIOLOGY OF THE GENUS ANASTATUS.

No complete account has been published to date on the life history of any species of the genus *Anastatus*. That of *A. bifasciatus* Fonsc., the imported egg parasite of the gipsy moth, is treated in a general way by Howard and Fiske (3) and Crossman (2), but the early stages of the larva are not described or figured. One generation per year is produced.

In 1921 Caffrey (1) published an account of the life history of *A. semiflavidus* Gahan, parasitic in the eggs of *Hemileuca oliviæ* Ckll., but in this case also the early larval stages are not discussed. The normal life cycle is stated to cover one year, though a portion of the generation prolongs the mature larval stage to the second year. This aestivation through an entire additional season is doubtless due to the extremely low humidity occurring during the time at which emergence takes place. This is similar in effect to the reactions of insects in tropical sections where no rainfall occurs during the winter months and atmospheric humidity is very low, development during this period being suspended in spite of the relatively high temperatures.

In discussing the irregular life cycle Caffrey also states that a portion of the eggs probably pass the winter as such, and that those deposited early develop partially and then reach the mature larval condition early in the spring. Considering the very short incubation period known for other species of the genus it is quite improbable that the eggs do carry over the winter, and the more normal condition is for the mature larval stage to be reached quickly, and before hibernation.

The sex ratio of *A. semiflavidus* was found to be 1 to 1.4 and 1 to 1.5, the females predominating, in the two series in which counts were made, and this is practically identical with that noted by the writer for *A. albitarsis.*

In two additional species of *Anastatus* reared by the writer from Pentatomid eggs in India during the past season the primary larvæ were identical in form with that figured by Parker and Thompson. The fleshy prongs upon the head of the pupa were lacking in these two species, as they are also in *A. bifasciatus* and *A. semiflavidus.*

Of the related genus *Eupelmus* accounts have been given of *E. allynii* French, parasitic externally upon *Harmolita tritici* Fitch and its other parasites, by Packard (4) and Phillips and Poos (7), and of *Eupelmus* sp. by Parker (5). The egg of *E. allynii* has a sharply pointed pedicel at the anterior end, while the long pedicel at the opposite end is delicate and collapses after the egg is laid. The primary larvæ of the above species, being external feeders, differ in form from that of *A. albitarsis* in lacking both the long ventral setæ on the body segments and the large bifurcate caudal process.

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EXPLANATION OF PLATE XXIII.

Anastatus albitarsis Ashm.

Fig. 1. Adult female. (× 25).
Fig. 2. The egg, showing larva just before hatching. (× 65).
Fig. 3. First stage larva, lateral view. (× 90).
Fig. 4. First stage larva, ventral view. (× 90).
Fig. 5. Second stage larva, ventral view. (× 50).
Fig. 6. Third stage larva, lateral view. (× 35).
Fig. 7. Head of third stage larva, anterior view.
Fig. 8. Pupa, lateral view. (× 40).
Fig. 9. Head of pupa, dorsal view.

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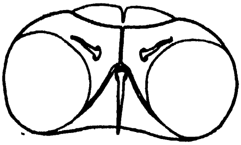

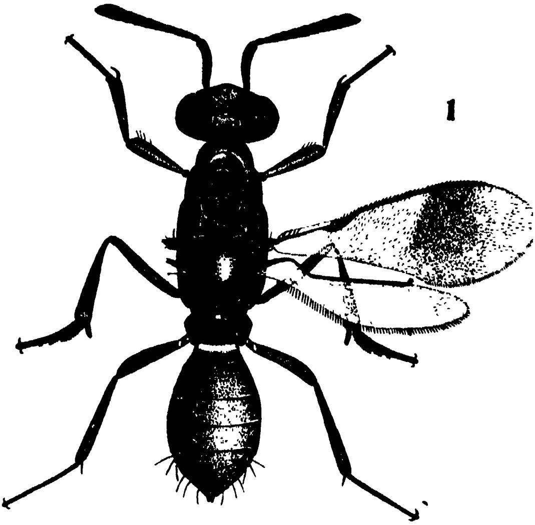

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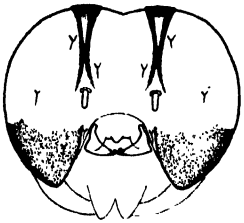

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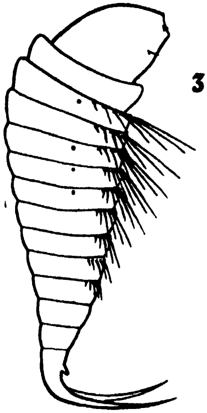

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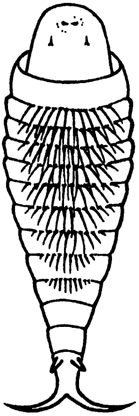

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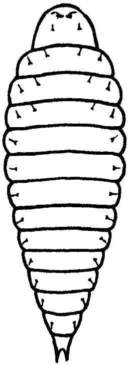

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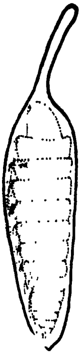

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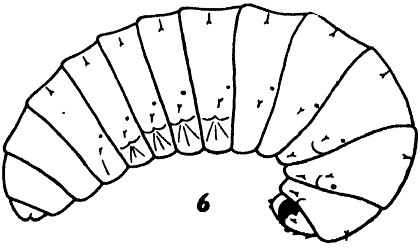

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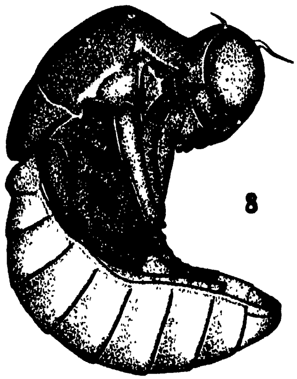

8

Curtis P. Clausen

THE AMERICAN CATOPSILIAS (LEPIDOPTERA, PIERIDÆ).

WM. T. M. FORBES,
Cornell University, Ithaca, N. Y.

The Rhodocerid group of Pieridæ fall into three sub-groups. One, composed of *Eurymus* (Colias) and *Meganostoma* is characteristically holarctic, and has invaded the tropical zone of both hemispheres only along the mountains. The second composed of *Dercas*, *Eurema* (Terias), *Teriocolias*, and *Nathalis* appears to have its most primitive forms in the tropics of the old world, though this is not quite certain, the typical genus Eurema being far more varied in America than in the old world. The third group, *Catopsilia*, *Kricogonia*, and *Gonepteryx*, is obviously tropical American, all the genera occurring in America, and only two limited groups of species having invaded the old world.

The genus Catopsilia was last reviewed as a whole by Butler in the Lepidoptera Exotica. Seitz's Macrolepidoptera of the World is hardly more than an illustrated catalogue in this genus, and makes no attempt at revision of the American names. It seems that a grouping of the species on structural characters and a key to the species might be useful.

The genus, as usually limited, falls into seven well-defined groups on the secondary sexual characters of the male; one of these including all the old-world species, while the rest are limited to America. To these I would add "*Gonepteryx*" *menippe*, as it is closely related to the old-world group of Catopsilia, and violates the definition of the otherwise homogeneous Gonepteryx. It might well be made one of the Old World group, with which it agrees in markings of the under side, as well as fairly well in sexual characters, but I have thought best to let it form an eighth group by itself. The groups form a fairly good linear series, but this arrangement is not a strictly evolutionary one. It would appear from the simplicity of secondary sexual structures and completeness of pattern (in sennæ), that the eubule group is perhaps most primitive.

Following are the groups:

A: **philea.** Mealy border extending almost to bases of cells down to M_2 or even M_3, then abruptly narrowed and marginal only from there down, also invading cell and extending in far toward base on inner margin. No hair-pencil. Sex patches on both wings where they overlap (easily seen by holding the butterfly to a bright light).

B: **eubule** (Callidryas). Mealy border similar, but with the abrupt decrease in width coming higher, the border being narrow in cell M_2 and sometimes even in R_5 and M_1, not invading cell. No hair pencil, no sex-patches.

C: **argante** (Phoebis). Mealy border all very narrow, not approaching the cell even on the costa; extended in on inner margin, especially narrow on hind wing. Hind wing with a hair-pencil but no sex-patch. Wings rounded.

D: **neocipris** (Metura). Similar, but the border very broad and even in width. Hind wing tailed at anal angle.

E: **trite** (Rhabdodryas). Border evenly broad, but little extended in on inner margin. Hind wing with a fringe of hair and a double sex-patch, riding on vein R, the fore wing without fringe or sex-patch.

F: **statira** (Aphrissa). Mealy border broad and even, about as in **trite,** but frequently invading the cell; ending abruptly on hind wing near Cu_1. No hair-fringe; sex-patches when present similar on both wings, rarely wholly absent, or indicated by an evanescent thickening.

G: **crocale** (Catopsilia). Mealy area covering almost whole upper surface of fore wing, and covering more than half of the cell, as in Kricogonia and Gonepteryx. Inner margin of **fore** wing with a fringe of hair, the hind wing without, but with a stigma. Old-world species, typically with a streak on under side of hind wing along top of cell, the costal region paler, as in Gonepteryx.

H: **menippe.** Mealy area confined to a large patch on **dorsal** half of wing, the apex plain. Hair-pencil on fore wing rudimentary, but with the lobe which should bear it particularly well marked. Hind wing with large sex-spot and broad mealy border.

KEY TO THE SPECIES AND FORMS (MALE).

A. Group *philea*.

1. Mealy area in cell M_3 extending nearly to its base, sometimes with a spot on the basal part of cell Cu_1 also; fore wing with a black discal dot, the orange or red oblique band larger below than in the cell (Antilles)........2

1. Mealy area in cell M_3 short, like those below; fore wing without a black discal dot, the orange band with part below cell of smaller area than part in cell (Mainland)..***philea**

2. Fore wing with anal angle more extended, under side with ground yellow, contrastingly marked and blotched with brown; upper side of wings with yellow and orange, but no red...........................***thalestris**

2. Fore wing more rounded; under side evenly and usually heavily dusted with dull red, without brown blotches; upper side extensively marked with vermillion..***avellanada**

B: Group *eubule.*

1. Mealy border narrower toward costa, the basal half of cell M_1 and frequently much of cell R_5 also, clear. Under side of hind wing usually immaculate or nearly so, (Atlantic States).................... ***e. eubule**
2. Mealy border nearly filling cells R_5 and M_1. Under side of hind wing normally with almost the complete maculation traceable, (Miss. Vall. to S. America, also Antilles)................................. ***e. sennæ**

The two subspecies appear to intergrade in the greater Antilles. *C. drya* is usually identified as a small form of *sennæ* from Chile. I am not sure that the form is distinct enough to have a name, as many Antillean specimens are no larger; and also the name *drya* probably does not belong to it. The discal dot of the fore wing below averages smaller in Chilean forms, even as compared with Antillean specimens of the same size.

C: Group *argante.*

1. Postmedial series of spots on under side of fore wing continuous, frequently represented mainly by a band of dark dusting............ ***agarithe**
1. Postmedial spot in cell M_3 well defined and far near margin than that in cell M_2 (*argante*)...2
2. Terminal black line of fore wing above continuous, at least toward costa, ab. ***hersilia**
2. Terminal series of black points only.............................. ***typical**

There appears to be some difference between Antillean and Mexican specimens of *agarithe,* at least in the female, where I have made a distinction in the key.

The S. Domingo race of argante (*rorata* Btl.) also is easily distinguished in the female. I have seen no males, and do not know how to separate it from typical argante. *Hersilia* is a partly racial form, apparently being more common on the mainland.

D: Group *cipris.*

1. Expanse over 70 mm.; base of fore wing sulphur yellow, only a little darker than the mealy border.. ***c. rurina**
1. Smaller, expanse under 70 mm.; base of fore wing bright orange yellow, contrasting... ***c. cipris**

These two forms appear to intergrade perfectly, and are not really even of racial value. They may be kept as dimorphic forms.

E: Group *trite.*

***C. trite** only. A very distinct and constant species.

F: Group *statira.*

1. Areas of sex-scaling on inner margin of fore wing and costa of hind wing long-elliptical, bluntly pointed at outer end. Fore wing above with a large nearly circular orange area on the basal half, contrasting with the lemon yellow at the apex of the cell and whiter mealy border........ **†orbis**

1. Areas of sex-scaling on overlap of fore and hind wings shorter, rounded-triangular, with truncate outer ends (rarely obsolete). Fore wing above with basal part wholly of one color, yellow or cream..............**2**
2. Under side with more or less distinct postmedial markings on both wings, (_godartiana_)..............**3**
2. Under side immaculate..............**4**
3. Pattern below nearly complete; upper side lemon yellow......**g. godartiana**
3. With postmedial markings reduced to a series of dots; upper side tinted with orange..............**g. hartonia**
4. No sex-marks at overlap of fore and hind wings; mealy border purer white than usual, under side pale, especially toward marginal half of hind wing..............***etiolata**
4. Sex-marks sharply defined, a little weak in _wallacei_, which has a yellow mealy border..............**5**
5. Yellow with white border; mealy area with a spot in end of cell (one specimen from Itaituba wholly white)..............***statira**
5. Wholly yellow, the border only slightly paler; typically without any mealy spot in cell.....*_neleis_ (Antilles); *_wallacei_ (N. South America)
5. Evenly pale buff or cream color, the border practically concolorous; mealy border of hind wing very broad..............***boisduvalii**
5. Similar, the basal part of the wing distinctly tinted with orange........**jada**

G: Group *_crocale_.

This group contains five or six old-world species, with numerous forms.

H: Group _menippe_.

This group contains the very distinct *_C. menippe_ only. It is generally put in Gonepteryx, and is perhaps actually a transition to that genus, but it lacks the usual angle on the hind wing, and seems not at all out of place in Catopsilia, where it is really close to florella.

ARTIFICAL KEY TO FEMALES

The following key is tentative and to a certain extent incomplete, but may serve as a guide. Females of Catopsilia are highly variable, especially in color, but also to a considerable extent in markings; and are also relatively rare both in collections and in the field. They are rarely taken in association with the males, and in the statira group we cannot yet safely match the various female types with their corresponding males. Butler attempted to do so, I think with partial success, and I have generally followed him. As to color, yellow and white females occur in almost every species, and orange ones also in the cases where the male is orange. There is also the orange C. jaresia Btl., (Pl. 51, Figs. 5, 6) which evidently belongs either to statira or the similarly colored etiolata, as those two species occur at the same place. As the markings are identical with undoubted statiras, from points where etiolata seems absent, in fact with Cramer's figure of the type, I suppose it is a color form of statira.

1. Very large; apex of fore wing shaded with orange; under side of hind wing with a pale shade along R.......... ***menippe**
1. Smaller; apex not shaded with orange; costal part of hind wing not specially marked.......... 2
2. Hind wing tailed (*neocipis*).......... 3
2. Hind wing rounded.......... 5
3. Small, ground evenly yellow.......... ***n. neocipris**
3. Larger; ground with white or red or both †*n. rurina*.......... 4
4. Yellow, marginal part of hind wing broadly shaded with red.......... **†typical**
4. Border narrow and more or less broken into a series of spots.... var. **intermedia**
4. White, without red border.......... var. **†virgo**
5. An even, continuous, sharply defined median line on hind wing, besides postmedial markings, and postmedian line on fore wing.......... ***trite**
5. No continuous dark line across the wings.......... 6
6. Under side of fore wing with postmedial spots ending abruptly at M_3; upper side normally with a continuous border extending below Cu_1, as well as a discal dot, but without postmedial markings (group *statira*).......... 15
6. Under side usually with a complete series of spots. Fore wing above with distinct postmedial spots, or else with the black border cut up into spots on the veins; (the pm. spots frequently partly fused with the border in *arganta*).......... 7
7. Postmedial series of spots on fore wing (visible at least beneath), continuous, with the spot in M_3 slightly farther from the margin than in M_2, **†agarithe**[2]
7. Postmedial spot below M_3 much closer to margin than that above M_3; in most cases (except group philea) only half as far from margin as the next one below it.......... 8
8. Discal dot of fore wing below always with a distinct portion lying above the origin of vein M_1, when the spot is large with this upper portion nearly as large as the lower. Spot in cell M_1 below only a little nearer margin than that in Cu_1, (group *philea*).......... 9
8. Discal dot normally small and wholly below M_2; rarely enlarged, but in that case with the part below M_2 several times as large as the part above, which may be a mere dot. Spots in cells M_2 and M_3 very obliquely placed.......... 12
9. Fore wing with border continuous and broad at apex; the outer margin practically straight; border of hind wing normally shaded with red.. ***philea**
9. Border weaker and broken into spots: outer margin strongly concave at middle.......... 10
10. Large; hind wing more or less suffused with red, sometimes almost wholly, but with paler base.......... 11
10. Smaller; hind wing with ground color nearly even; orange or yellow in the specimens examined.......... **†thalestris** (S. Domingo race)[3]
11. Under side of hind wing ochre yellow with contrasting dark brown markings and shadings.......... **†thalestris**
11. Under side of hind wing with ground color evenly dusted with red, usually heavily, the markings not contrasting.......... **†avellanada**
12. Apex typically with a black patch involving the postmedial spots in cells R_3 and R_5, the spot in cell M_1 often also connected; if reduced with the border of the hind wing reduced to small dots.......... (**argante**) 13
12. Apex with a narrow border, separate from the postmedial spots, save in occasional specimens which have a complete border on the hind wing, (*eubule*).......... 14

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[2] The typical form is heavily marked with black on the upper side, much like **C. argante**; in the Greater Antilles there is a female with the black much reduced, the border mainly represented by a small apical spot, and small terminal dots below (**floridensis**). This is the form which Butler figures as agarithe.

[3] This is editha ♀ of Butler.

13. Ground orange, yellow or white, with little or no red dusting.....***a. argante**
13. Ground heavily dusted with deep Indian red....................**†a. rorata**
14. Under side with all the markings small and well separated; upper side normally with discal dot on fore wing the most conspicuous mark..***e. eubule**
14. Under side with markings heavy and connected, frequently also dusted with reddish; upper side with border strongly developed, the discal dot less conspicuous..***e. sennæ**
15. Upper side of fore wing with postmedial dots above M$_3$................**orbis**
15. Upper side without postmedial dots or with traces of tawny ones..........16
16. Upper side of fore wing with well marked black border, but no discal dot at all....................................**†wallacei** (supposition)
16. Discal dot distinct...17
17. Discal dot moderate in size, and limited to the lower disco-cellular vein; black border traceable on hind wing as well as strong on fore wing, ***statira** 18
17. Discal dot large, and resting on the middle as well as the lower disco-cellular, sometimes the whole height of the cell; a little smaller when the border is reduced to a slender line on the fore wing only..............19
18. Ground orange..***ab. jaresia**
18. Ground yellow or ochreous, much paler on marginal half.............***typical**
19. Ground wholly buffy cream, concolorous with male..............**†boisduvalii**
19. Basal half of wing bright yellow, or orange...............................20
20. Solid bright yellow; border reduced to dots.......................**†neleis**
20. Yellow, border continuous..21
20. Much shaded with orange; border very heavy...................**godartiana**
21. Discal dot on lower dcv. only; border almost enclosing a yellow subapical spot...**jada**
21. Discal dot extending up on mdcv. border entire..................**hartonia**

DESCRIHTION

C. **etiolata** new species

Closely similar to *C. statira* and usually confused with it. Mealy border narrower, usually reaching close to the lower angle of the cell, but rarely with a spot within the cell, sex spots on inner margin of fore wing below and costa of hind wing above, very obscure, without definite boundary and barely visible when the specimen is held against a strong light. Color and markings almost identical with *C. statira,* except that the narrower mealy border is plainly shown as a narrower pure white outer half of the wing, the cell being wholly yellow. Hind wing beneath paler than in *statira,* typically light yellow at the base, gradually shading into cream white at the outer margin. 55mm.

Holotype and several paratypes from the Lower Pachitea River, Eastern Peru, July 22, 1920; Cornell University, Lot 607, Sub 143, type No. 835; also paratypes from Puerto Bermudez, Rio Pichis, Peru, July 17; Azupizu, Camino del Pichis, Peru, July, San Carlos (Mapiri), Bolivia (O. Buchtien coll.); Itaituba and Santarem on the lower Amazons (H. H. Smith); Chanchamayo District, Peru (Sarco); Serra Cantareira, S. Paulo, Brazil, Mar. 1903 (Hammar) (not typical). A specimen labelled as from New Mexico is probably in error (Foulks Coll.). The species is also in the American Museum of Natural History from Venezuela, and is probably generally confused with *C. statira.*

It would appear that this is a distinct species, considering the difference of structure, and the considerable number of like specimens. There are, however, a few specimens that seem to show intergrading or hybridization with *C. statira*, either showing the lack of sex-patch with the narrow mealy border (Itaituba, Amazons, H. H. Smith) or a broad mealy border entering the cell, with the intense white color of this species and no sex-patch (Yurimaguas, Peru, Mar. 25, 1920, H. S. Parish) or else the deeper buff under side (Colombia and R. Uaupes, N. W. Brazil, in American Museum). *C. wallacei* is also very near, and was apparently confused with this form by Butler, who figured it with the characteristic pale under side of this form; but the series which I identify as *wallacei* (From Kartabo, British Guiana) have a decidedly yellow border, and a definite though not conspicuous pair of stigmata, they also have the deeper yellow under side of the original description.

I have not recognized the female, it may be *jaresia* Butler, which H. H. Smith took in association with *statira* and *etiolata*, or the form which I have entered in the key as possibly the female of *wallacei*.

LIST OF NAMES.

A. **philea.**
1. philea
syn. ♀ *forna*
2. thalestris
a. editha (♀)
3. avellanada
syn. solstitia

B. (**Callidryas**) **eubule.**
4. eubule
a. sennæ
syn. marcellina
syn.? drya
syn.? editha ♂
syn. ♀ *cipris Cr.*
♀ ab. yamana
syn. pallida

C. (**Phoebis**) **argante.**
5. agarithe
a. floridensis
6. argante
var. hersilia
ab. minuscula
a. rorata

D. (**Metura**) **neocipris.**
7. neocipris
syn. cipris F.
a. rurina
♀ ab. virgo
♀ ab. intermedia

E. (**Rhabdodryas**) **trite.**
8. trite

F. (**Aphrissa**) **statira.**
9. statira
syn. ♂ *alcmeone*
♀ ab. jaresia
10. etiolata
syn. wallacei Btl.?
11. wallacei Fld.
12. neleis
13. godartiana
a. hartonia
14. boisduvalii
syn. butleri
a. jada
15. orbis

G. (**Catopsilia**) **crocale.**
16. pyranthe
17. florella
18. crocale
19. pomona
20. scylla

H. **menippe.**
21. menippe

THE EXTERNAL ANATOMY OF THE LARVA OF HOPLOCAMPA HALCYON NORT. WITH A KEY TO THE INSTARS AND TO THOSE OF RELATED SPECIES (TENTHREDINIDÆ, HYMENOPTERA).*

By RALPH D. BIRD.

The following account is based on a series of larvæ bred by the writer while studying the life histories of sawflies in southern Manitoba. The species concerned are, the Saskatoon sawfly (*Hopocampa halcyon* Nort.) which breeds in the fruit of *Amelanchier spicata*, and *Hoplocampa xantha* Rohwer and *Hoplocampa* (*MacGillvrayella*) *lacteipennis* Rohwer both of which as larvæ bore in the fruit of *Prunus virginiana* (1, 2).

Until more specimens of the larvæ of the subfamily Hoplocampinæ (Hemichroini) Rohwer (3) are available for study it will be impossible to make a key to separate the genera. The species studied run to the genus *Marlattia* in Yuasas key (4) to the Hoplocampinæ, but they may be separated from this genus by the pigmentation of the anal segments and the total lack of coloration of any areas not heavily chitinized.

In order to bring out the external characters of the larvæ of the genus *Hoplocampa* a study was made of the fifth instar of *H. halcyon* Nort. and characters found to be of specific value for separating the species concerned are shown in the comparative table and key. Special attention was paid to the spines on the lacinia, epipharynx and front, but they were found to be variable and of no specific value as was also the shape of the labrum.

In general it may be said that the larvæ studied typically have five annulets on the abdominal segments; two large setæ on the labrum; very short, conical, three-segmented antennæ; two-segmented labial and four-segmented maxillary palpi, and pigmented areas on the dorsum of the anal segments. All are borers in fruit.

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*Contribution No. 114, from the Entomological Laboratories, University of Illinois, Urbana, Illinois.

THE EXTERNAL ANATOMY OF *Hoplocampa halcyon* NORT.

The larva of *Hoplocampa halcyon* Nort., like those of all the Tenthredinidæ, with the exception of the leaf-miners is cylindrical in form and caterpillar-like. It has a sub-globular head and a series of thirteen well defined segments. Its thoracic legs are well developed. In addition its ten-segmented abdomen bears a pair of fleshy protuberances or prolegs on the latero-ventral aspect of segments two to seven and ten. These differ from those of the lepidopterous larvæ in the absence of a circlet of terminal hooks or crochets.

The head.—(Figs. 3, 5 and 11). The head capsule is brown, slightly roughened and is covered with a few short setæ. It bears an inverted Y-shaped median epicranial suture. The stem of the "Y" (ES) originates at the occipital foramen, extends cephalad, dividing the vertex into two halves and bifurcates in a central position of the cephalic aspect of the head. Each arm (EA) of the bifurcation after extending obliquely laterad for a short distance then bends ventrad to the ventral margin of the capsule where it terminates near the subtriangular clypealia (CL). The dorsal, lateral, and the greater part of the cephalic and caudal aspects of the head form an area, the epicranium, which is subdivided into three definite areas, the vertex (V), the genæ (G) and the front (F).

The vertex (V) extends from the stem of the epicranial suture to the ventral margin of the head, laterad of the epicranial arm and cephalad of the occipital suture (OS). It bears an ocularium (O) and an antennaria (A). A vertical furrow (VF) extends on each side of the vertex from the occipital foramen cephalad for a considerable distance on the lateral aspect of the head.

The genæ (G) occupy that portion of the vertex ventrad of an imaginary line drawn ventrad of each ocellus parallel to the ventral margin of the head capsule.

The front (F), that area on the cephalic aspect of the head bounded by the epicranial arms, is pentagonal and as long (dorso-ventrally) as wide (laterally). It is slightly concave and bears a few setæ which vary with the individual.

The oculariæ (O) are situated, one on each side of the head at about their own width dorsad of the antennæ. They are round, black and bear in their center a clear semiglobular ocellus.

The antennæ are situated near the center of a whitish, oval antennaria (A). They are composed of three joints, the first of which is incomplete ventrally. They are very short and each about one half the diameter of the preceding.

The clypeus is a narrow sclerite bounded dorsally by the fronto-clypeal suture (FC) and ventrally by the clypeo-labral suture (CLS). Its lateral margins are free and converge ventrally at an obtuse angle. It is divided into a preclypeus (PE) and a post-clypeus (PO) by the clypeal suture (CS).

The lobe-like labrum (L) has a shallow, broad emargination on its ventral margin. Two lateral setæ are borne on each side of the meson.

The postgenæ (PA) include those areas between the occipital suture and the body of the tentorium (MT).

The feebly developed maxillariæ (MA) bound the dorsal margin of the oval occipital foramen (OF).

The mouthparts.—The larvæ of *Hoplocampa halcyon* like those of other Tenthredinoidea possess well developed mandibulate mouthparts consisting of a pair of mandibles, a pair of maxillæ and a labium.

The mandibles (M and Fig. 8) are short, thick and strongly chitinized. They bear at their distal end four dentes, the two lateral ones of which are much smaller than the two mesal ones.

The maxillæ (MX and Fig. 9), as is typical consist of a cardo, stipes (S), palpifer (PF), palpus (MP), galea (GL) and lacinia (LA). The cardo is divided into a large alacardo (AC) and a small subcardo (C). The alacardo is a rhomboidal sclerite articulating with the stipes on its latero-proximal aspect. The subcardo is a small triangular sclerite at the proximal end of the alacardo. The stipes which constitutes by far the largest part of the maxilla is not as heavily chitinized as the cardo. It is convex on its lateral aspect, while the cephalic aspect is membranous and continuous with the maxacoria. Along the mesal aspect of its caudal margin it is fused to the elongate subgalea (SG) by a distinct chitinized ridge which extends from the lateral margin of the alacardo to the lacinia. The palpifer at the cephalic margin of the stipes is sub-globular and bears two large setæ on its lateral aspect. The maxillary palpus (MP) consists of four, conical segments of approximately the same length but successively smaller in diameter. On the disto-mesal margin of the third segment there is a row of four setæ. The galea (GL) is a blunt, unsegmented projection smaller than the maxillary palpus and curved mesad slightly. The lacinia (LA) is flattened and bears a row of five to seven setæ on its distal edge.

The labium (LI and Fig. 10), consists of submentum (SM), mentum (ME), palpifer (PF), a pair of labial palpi (LP) and a subglobular lobe (HX) representing the fused glossæ and paraglossæ. The mentum (ME) is large and has six prominent setæ, two just below each palpifer and one on each lateral margin. The submentum (SM) merely consists of a band-like chitinous area separated from the mentum by a membrane equal to it in width. The palpiger (PG) is well developed and the palpi consist of two conical segments.

The prepharynx (hypopharynx) is a simple lobe-like organ situated between the laciniæ of the maxillæ. As it is not strikingly modified in the various families of the Tenthredinoidea (4) it is not figured for this species.

The epipharynx (Fig. 4) bears a characteristic group of setæ the number and shape of which are variable with the individual.

The cervacoria is the membranous area connecting the head and prothorax. It is supported on each side by a triangular, brown, cervical sclerite not shown in the figures.

The thorax.—(Fig. 3), is only feebly chitinized and is strongly declivitous on the dorsal aspect, which is divided more or less completely into four annulets in each segment. The metathorax and pro-thorax bear spiracles (SPI), the latter supposedly a mesothoracic spiracle which has moved forward.

The thoracic legs.—(Fig. 7). Each segment of the thorax bears a pair of typical, well developed legs consisting of five segments, coxa (CX), trochanter (TR), femur (FM), tibia (T) and a distal segment (CW) representing the fused tarsus and tarsal claw (Yuasa).

The abdomen.—(Figs. 1, 2 and 6), is cylindrical, glabrous and bears a pair of prolegs on segments 2-7 inclusive and 10. All but the last three segments are subdivided into five annulets. The most typical segment is the third (Fig. 2) which also bears well developed subspiracular (SL) and surpedal (SP) areas and is annulated on the sternum as is shown in figure 6. No ventral glands were found. The terga of the eighth, ninth and tenth segments are not annulated, but are heavily chitinized and spotted with black. There is no suranal process or caudal protuberance of any kind.

TABLE FOR THE IDENTIFICATION OF LARVAE.

Hoplocampa halcyon Nort., *H. xantha* Roh. and
H. (*MacGillvrayella*) *lacteipennis* Roh.

	H. lacteipennis	*H. halcyon*	*H. xantha*
First instar	Tergum ten black; black patch on anal prolegs; head width 0.22 mm.; length 1.3 to 1.86 mm.	Tergum ten and nine black; head width 0.25 mm.; length 1.4 to 3 mm.	Tergum ten and part of nine black; head width, 0.29 mm.; length 1.23 to 2 mm.
Second instar	Tergum ten and nine black; head width 0.39 mm.; length 1.88 to 3.35 mm.	Tergum, ten, nine and eight black; head width 0.4 mm.; length 3 to 5 mm.	Tergum ten, nine and part of eight black; head width 0.4 to 0.45 mm.; length 2 to 4 mm.
Third instar	Tergum ten and part nine of light yellow; head width 0.59 mm.; length 3.4 to 7.8 mm.	Tergum ten, nine, eight and part of seven black; head width 0.61 mm.; length 4 to 6 mm.	Tergum ten, nine and eight black; head width, 0.65 mm.; length 4 to 5 mm.
Fourth instar	Abdomen wholly white; head width 0.88 mm.; length 7.8 to 9 mm.	Tergum ten and nine spotted with black; head width 0.9 mm.; length 6 to 7.2 mm.	Tergum ten, nine and eight yellow spotted with black; head width, 0.9 mm.; length 5 to 7 mm.
Fifth instar	No fifth instar.	Tergum ten, nine and part of eight spotted lightly with black; head width 1.0 mm.; length 6.5 to 9 mm.	No fifth instar.
Food Plant	***Prunus virginiana***	***Amelanchier spicata***	***Prunus virginiana***
Larval Period at Aweme, Manitoba.	**May 15 to July 31**	**May 15 to June 29**	**May 15 to June 25**

KEY TO THE INSTARS.

Hoplocampa halcyon Nort., *H. xantha* and *H.* (*MacGillvrayella*) *lacteipennis* Roh.

A. Tergum of abdominal segments solid black.

B. Tergum of tenth segment only, black.

C. Black on posterior part of anal prolegs. Borer in the fruit of *Prunus virginiana*...**1st instar of H. (MacGillvrayella) lacteipennis.**

CC. No black on anal prolegs. Borer in fruit of *Prunus virginiana*, ...**1st instar of Hoplocampa xantha.**

BB. Tergum of ninth and tenth segments black.

C. Length 1.88 to 3.55 mm. Width of head 0.35 to 0.4 mm. Borer in fruit of *Prunus virginiana*, ... **2nd instar of H. (MacGillvrayella) lacteipennis.**

CC. Length 1.2 to 2 mm. Width of head 0.25 to 0.3 mm.

D. All of terga of segments nine and ten black. Borer in fruit of *Amelanchier spicata*, ...**1st instar of Hoplocampa halcyon.**

DD. All of tergum of tenth segment black and only the posterior part of the ninth. Borer in the fruit of *Prunus virginiana*, ...**2nd instar of Hoplocampa xantha.**

BBB. Tergum of eighth, ninth and tenth segments black.

C. Black patch on the caudal aspect of anal prolegs. Length, 4 to 5 mm. Width of head, 0.6 to 0.7 mm. Borer in fruit of *Prunus virginiana*, ...**3rd instar of Hoplocampa xantha.**

CC. No black on anal prolegs. Length usually less than 5 mm. Head not wider than 0.5 mm.

D. All of terga eight, nine and ten black, sometimes a very small black spot on the mesodistal end of segment seven. Borer in the fruit of *Amelanchier spicata*, ..**2nd instar of Hoplocampa halcyon.**

DD. All of terga nine and ten and only part of eight black. Borer in fruit of *Prunus virginiana*, ..**2nd instar of Hoplocampa xantha.**

BBBB. Tergum of eighth, ninth, tenth and part of the seventh segments black. Borer in fruit of *Amelanchier spicata*, ...**3rd instar of Hoplocampa halcyon.**

AA. Tergum of terminal abdominal segment merely spotted with black, if at all.

B. Terminal abdominal segments white. Width of head about 0.88 mm. Borer in fruit of *Prunus virginiana*, ...**4th instar of H. (MacGillvrayella) lacteipennis.**

BB. Tergum of ninth and tenth segments light yellow (may be faded out in alcoholic specimens). Width of head, 0.6 mm. Borer in fruit of *Prunus virginiana*, ...**3rd instar of H. (MacGillvrayella) lacteipennis.**

BBB. Tergum of ninth and tenth segments spotted with black. Width of head about 0.8 mm. Borer in fruit of *Amelanchier spicata*, ...**4th instar of Hoplocampa halcyan**

BBBB. Tergum of eighth, ninth and tenth segments spotted with black.

C. Terga white with black spots and only part of the eighth spotted. Borer in fruit of *Amelanchier spicata*, ...**5th instar of Hoplocampa halcyon.**

CC. Terga light yellow with black spots. All of the eighth spotted. Borer in the fruit of *Prunus virginiana*, ...**4th instar of Hoplocampa xantha.**

The writer would like to express his indebtedness to Dr. W. P. Hayes of the Department of Entomology, University of Illinois, under whom the work was done for many valuable suggestions and criticisms in preparing the manuscript.

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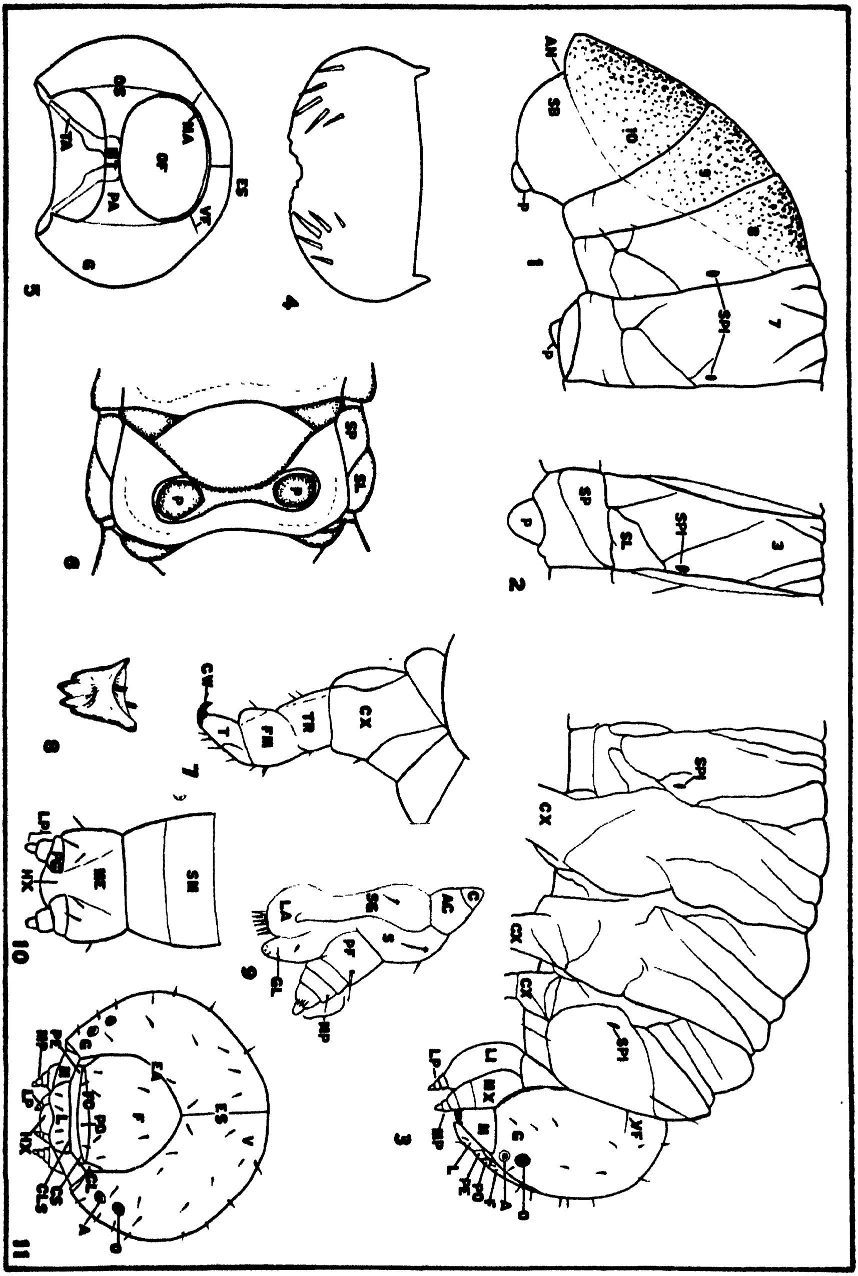
EXPLANATION OF PLATE XXIV.

The Larval Anatomy of *Hoplocampa halcyon* Nort.

Fig. 1. Lateral aspect of caudal abdominal segments. × 45.
Fig. 2. Lateral aspect of third abdominal segment. × 45.
Fig. 3. Lateral aspect of head and thorax. × 45.
Fig. 4. Epipharynx. × 160.
Fig. 5. Caudal aspect of head capsule. × 45.
Fig. 6. Ventral aspect of third abdominal segment. × 45.
Fig. 7. Caudal aspect of prothoracic leg. × 160.
Fig. 8. Mandible. × 160.
Fig. 9. Right maxilla. × 160.
Fig. 10. Labium. × 160.
Fig. 11. Cephalic aspect of head capsule. × 45.

LIST OF ABBREVIATIONS.

A	antennaria.
AC	alacardo.
AN	anus.
C	subcardo.
CL	clypealia.
CLS	clypeo-labral suture.
CS	clypeal suture.
CW	tarsal claw.
CX	coxa.
EA	epicranial arm.
ES	epicranial stem.
F	front.
FC	fronto-clypeal suture.
FM	femur.
G	galea.
HX	fused glossæ and paraglossæ.
L	labrum.
La	lacinia.
LI	labium.
LP	labial palp.
M	mandible.
MA	maxillariæ.
ME	mentum.
MP	maxillary palp.
MT	body of tentorium.
MX	maxilla.
O	ocellus.
OF	occipital foramen.
OS	occipital suture.
P	pseudopod.
PA	postgena.
PE	preclypeus.
PF	palpifer.
PG	palpiger.
PO	postclypeus.
S	stipes.
SB	subanal lobe.
SG	subgalea.
SL	subspiracular lobe.
SP	surpedal lobe.
SPI	spiracle.
T	tibia.
TA	tentorial arm.
TR	trochanter.
V	vertex.
VF	vertical furrow.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Ralph D. Bird

FURTHER STUDIES ON THE GENUS GYPONA AND IT'S ALLIES (RHYNCHOTA, HOMOPTERA).

By E. D. BALL AND J. A. REEVES.

The systematic relations of this group were briefly discussed by the senior author in a previous paper.* It was recognized at the time as only a preliminary and tentative classification, hastily brought together and published in the hope of correcting a number of serious errors before they became established in the literature. During the past two years a number of the relatively rare species and varieties have been taken in numbers and food plants and life history observations on these and other species accumulated.

With the idea of more fully establishing the generic and specific limits in the group the junior author undertook to study the internal genitalia of all the available forms occurring in the United States. These studies not only confirmed the validity of the generic divisions established but definitely indicated that at least one more distinct generic group was advisable. The five divisions of the old genus *Gypona* all show distinct and strikingly different types of internal genitalia. *Dragonana* in many characters is more closely allied to *Xerophloea* than to *Gypona* proper and these two genera may well represent one line of development while the remaining genera represent another. *Dragonana* is either primitive or degenerate as judged by the simple internal genitalia. If we recognize irregularly recticulate venation as an indication of primitive character, as we probably must, then *Dragonana* may well represent the most primitive condition found in the group in our region, followed by *Gyponana*, *Gypona*, *Prairiana* and *Ponana* in the order named.

Gyponana rugosa is quite distinct in a number of characters from the other members of that genus and further study may warrant its segregation. Its internal genitalia are in certain characters very close to those of *Gypona glauca*, the type of the latter genus, and may indicate the line of divergence of the other groups from a primitive *Gyponana* type of ancestor.

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*Ball, E. D. Annals Ent. Soc. Amer., Vol. XIII, p. 83-96, 1920.

The three species of *Prairiana* are strikingly distinct in their complicated pattern of internal genitalia and show closer affinities with *Ponana* than with *Gypona*. *Ponana resima* has been considered the extreme modification in this complex type, on the other hand it may represent a primitive type. An extended study of the South American forms will be necessary to determine this. The pygofers in this species carry a long curved spine, a character not observed in any other member of this group.

KEY TO THE N. A. GENERA OF GYPONINAE.*

A. Dorsal surface or at least elytra deeply pitted, body doubly wedge-shaped, elytra becoming vertical towards apex.
  B. Pronotum pitted, front narrow, elongated, spines on hind tibia few, 1. **Xerophloea** Germ.
  BB. Pronotum striate, front broader wedge-shaped, spines on hind tibia numerous, stout....................................2. **Dragonana** Nov.
AA. Dorsal surface not pitted except possibly along veins, body elongate or oval, elytra not appressed at apex.
  C. Elytra reticulate, or at least apically............ 3. **Gyponana** Ball.
  CC. Elytra with the venation regular or nearly so.
    D. Face and vertex meeting in an acute angle, margin foliacious.
      E. Elytra without markings in areoles, species green, golden or black..4. **Gypona** Burm.
      EE. Elytra with dots or lines in areoles, species straw or smoky, 5. **Prairiana** Ball.
    DD. Vertex rounding to face or overhanging, rarely with a slightly produced thick margin.
      F. Elongate, clypeus acute, elytra not overlapping..6. **Ponana** Ball.
      FF. Oval, clypeus truncate, elytra broadly overlapping posteriorly, 7. **Penthimia** Germ.

Genus **Dragonana** nov.

Intermediate in form and structure between *Gyponana* and *Xerophloea* with the pronotum definitely broadened and almost angled posteriorly. This broadening serves as the base of a short blunt anterior triangle and also of a long acute posterior one. Head much narrower than body, vertex obtusely angular, lower than the plane of the pronotum, the anterior margin slightly foliaceous. Ocelli on the vertex about equidistant between the anterior and posterior margins and between themselves and the eyes. Front narrow, flat, slightly wedge shaped as in *Gyponana*. Pronotum transversely striated, convex in

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*Fowler in the Biologia lists *Epiclines* A. and S. (from India) with a single (new) species from Mexico and Central America, but omits *Xerophloea*, which occurs throughout both North and South America. There is nothing in Fowler's figure or description that might not apply to a large species of *Xerophloea* and it has been thought best to omit *Epiclines* from consideration as a New World form until the generic relationships can be determined.

both diameters, the anterior submargin very much depressed, rounding in front, straight behind. Elytra long, relatively narrow, appressed posteriorly, becoming vertical at the tip. Whole surface closely pitted or ornamented with setigerous pustules. Venation weak and indefinite with some irregular reticulations in the forks and toward the apex. Whole surface milky subhyaline with dark setigerous punctures.

Type of Genus *Gypona dracontia* Gib. (Ariz.).

This genus is quite distinct structurally and probably represents a more primitive type than either *Gyponana* or *Xerophloea*. Superficially this species might be taken for a *Xerophloea* but the members of that genus have the head and pronotum pustulate instead of striate and the elytra have a definite cell pattern toward the apex.

Gyponana octolineata Say.

This is one of the most puzzling and variable forms in the whole group and has been the subject of much difference of opinion as to specific and varietal limits. It ranges from coast to coast and from Canada to Mexico and probably on to South America. It is the most abundant species in most of its range and varies from small pale forms of 9 or 10 mm. to the robust ones of 13 or 14 mm. in length. Certain forms are heavily and irregularly reticulate while in others the reticulations are reduced to a few extra ones in the apical and anteapical cells. The authors have studied external structures and internal genitalia throughout and have found no character that is not widely variable if the series studied is large enough.

The following varieties seem to be relatively constant. They are for the most part correlated with differences in food habits or life histories which probably explain the partial segregation.

KEY TO THE VARIETIES.

A. Scarlet, or at least stripes and reticulations scarlet..1. **octolineata** Say
AA. Green or green with yellow stripes on vertex and pronotum.
  B. Elytra heavily and irregularly reticulate, usually including all or part of clavus....................................2. **cana** Burm.
  BB. Elytra not reticulate at base or on clavus, sometimes with only a very few reticulations.
    C. Species large, 10 mm. or over, the apical part of elytra reticulate; often either striped with yellow or pruinose.
      D. Green with or without yellow stripes..............3. **striata** Burm.
      DD. Pruinose..4. **pruinosa** Spbg.
    CC. Smaller, narrower forms, green shining, found on pine..5. **tenella** Spbg.

Var. *octolineata* Say is the "pink katydid" expression of this species and probably does not represent a true variety in nature and yet certain puzzling variations need to be considered before uniting it with the second. It is found from Missouri and Minnesota eastward to the Atlantic, a region in which *striata* is the dominant form and yet the red *octolineata* forms are often heavily reticulated and apparently cannot be simply a red phase of the less reticulate variety.

Var. *cana* Burm. a short compact heavily reticulate form occurs in less numbers than *striata* from the Atlantic to the Pacific and from Canada to Mexico. It appears to be more abundant in the extreme southern region of the U. S. Nymphs and adults have been taken in numbers from the shrubby growths of the Florida flat woods. The nymphs are usually heavily dotted with brown and frequently margined with reddish brown. They are more abundant on *Pyrus* and *Vaccinium* than on the Myrtles. Burmeister describes this form as with an angulate vertex, but only an occasional example shows this character. He gives the length the same as that of *striata* but on the average *striata* will run a millimeter longer and all the extremely large examples seen have been of that form.

Var. *striata* Burm. is the commonest form found on the Pacific Coast and as stated above the dominant one in the Northern U. S. and Canada. The largest forms found in the United States (often as much as 13–14 mm. in length) are found here. The nymphs are found in almost all situations where mixed vegetation, weeds and shrubs occur. These are rare in pure grass stands or on isolated trees or pure tree stands. The true character of *G. quebecensis* Prov. has been a puzzle. Van Duzee insists that it is distinct, and characterizes it as small and heavily reticulate, although after he examined the Provancher collection in the museum at Quebec he recorded the specimen found there as a typical *cana*. Osborn in his Leafhoppers of Maine describes a small (8–9 mm.) slightly reticulate form as *cana* and lists *quebecensis* as a synonym, but Van Duzee in his catalogue places this reference under *quebecensis* despite the sparse reticulations. There appears to be no reason to believe that *quebecensis* is other than a synonym of *striata*, the common form in the region where Provancher worked. He recognized and described two species and only two, *quebecensis* = *striata* and *hullensis* = *pectoralis*, the two common forms found there.

He says nothing about reticulations, but gives the length as longer than *pectoralis* and its occurence as in damp places which would be correct for *striata*, but would not fit in with the idea of a small species, such as Van Duzee and Osborn describe or with *tenella*, the only small form occurring in that region that we have been able to differentiate.

Var. *pruinosa* Spgb. Spangberg described this form from Georgia and Texas placing it between *flavolineata* and *scrupulosa*, both forms of *striata* without giving any character by which it could be separated except the name. Certain pruinose forms from that region resembling *striata* have been placed here, but at the best it is a weak variety and pruinose forms also occur in *tenella*. The size given and the location in his system both incline one to believe that this is a pruinose variety of the larger forms.

Var. *tenella* Spgb. (*Gypona geminata* Osb. *Gypona quebecensis* Van Duzee, and Osb. in part (not Prov.). This is a small (7–9 mm.) pale green, almost parallel margined variety with relatively few reticulations; in some of the smaller examples they are almost absent. Some of the Northern examples have relatively strong reticulations in the anteapical and apical regions and may be what Van Duzee had in mind as *quebecensis* and what Osborn referred to in his Maine list. Provancher, however, described a larger insect, as noted under *striata*.

Osborn records it from pine on Long Island. Examples are at hand from Cranberry Lake, N. Y. (Osb. and Drk.). The senior author has taken it from Jack Pine in Northern Wisconsin, in August, and the writers have taken it commonly from Long-Leaf Pine in a number of places in Florida during the past two years.

The usually smaller. size and shorter head, as well as its association with pine, would seem to warrant specific rank, but a study of internal as well as external genitalia of numerous examples from Florida and Wisconsin compared with a long series of *striata* and *cana* from Florida, District of Columbia, Wisconsin, Iowa, Colorado, Utah and California shows no more than individual variation throughout the series.

Examples of a pruinose form of this species from Southern Florida, also taken on pine, and an example from Costa Rico extend the distribution and suggest further synonymic complications when the Mexican and South American tangle is worked out.

It was through a misinterpretation of Spangberg's comparison of this species with *bigemmis* that it was placed as a synonym of *angulata.* The smaller size (7–8 mm.), round head and pale color described all fit this form much better than any other occurring in the Georgia region.

Gyponana rugosa Spgb.

Specimens of this species are at hand from Boston, Mass., District of Columbia, Virginia, Wisconsin, Southern Colorado, and Salt Lake, Utah, all collected by the senior author from oak; specimens have been examined from Texas, New Mexico and several places in Arizona and Costa Rico. The writers have found nymphs and adults on nearly all species of oaks in Florida. It is apparently, only limited in distribution by the range of its food plant, the oaks.

The species, while heavily reticulated, is quite distinct in the genus *Gyponana* and in other characters is very close to *unicolor* and its relatives in *Gypona.* The nymphs are thickly covered with long silky hairs, while the nymphs of other species have relatively inconspicuous ones.

Gyponana chadana nov. sp.

Similar to *rugosa,* but smaller with narrower head and a long and acutely angled vertex. Length, 8 mm.

Head much narrower than pronotum, vertex almost as long as pronotum, right angled, with the margin very slightly convex; ocelli almost equidistant between base and apex, set well in front of eyes, equidistant from each other and the line of the eyes; front narrow, inflated so as to appear straight to the apex of the vertex in profile. Pronotum broad and short, rapidly narrowing from the prominent lateral angles to the very small eyes; elytra resembling *rugosa* in the type and pattern of reticulation, but narrowing posteriorly and lacking an appendix.

Color pale golden as in *rugosa* (greenish in life) but lacking the stripes of that species except a pair on scutellum. A pair of black spots on pronotum, another on hinges and milky white markings between the reticulations as in *rugosa.*

Holotype male, "Chads," Utah, July 11, 1910 (Ball). Swept from oak (*Q. undulata* var. *wrighti.*). This is a strikingly distinct addition to this group. In head character it resembles *angulata,* but is much narrower and even more acutely angled, while in other characters it is close to *rugosa,* but again narrower and more acute at the apex of elytra.

Gypona signoreti Stal.

This species varies from golden green to tawny or even reddish with a smoky cloud in the apical cells. The females are about the size and shape of the western males of *unicolor*, but with a shorter and less foliaceous vertex. This species was described from Mexico and the female examples are at hand from Salt Lake, Utah in August, and Cedar City, Utah in September taken on oak (Ball).

Var. *pilula* nov. Intermediate in form and color between *tenella* and *signoreti*. Smaller than *tenella* (7 mm.) golden or bright straw (green in life), with red eyes and ocelli, vertex quite definitely but slightly obtusely angulate, front slightly inflated so as to almost eliminate the foliaceous margin, female segment truncate, veination as in *unicolor*.

Holotype female, Allotype male and four Paratypes collected by Ball at "Chads," Utah, July 11, 1910, on *Cowania mexicana*. The material reported as *unicolor* by Ball from Arizona and that collected on oak at Dolores, Colo., (Aug., 2, 1900) belongs to this variety. A nearly full grown nymph was taken with the types. *G. signoreti* appears to be widely distributed through Mexico, the West Indies and on to South America and no doubt there will be some synonomy and many of its varieties will have been named, but most of its variations in the humid tropics are towards the reds with dark margins, while this form from the extremely arid dwarf oak environment, is strikingly small and pale.

Gypona unicolor Stal.

Gypona melanota Spgb., *G. bipunctulata* Wood., *G. nigra* Woodw., *G. germari* Fowl. (not Stal).

This large, broad, green, species with five varieties of males ranging from pure green to shining black is now known from Massachuesetts to Utah and south to Georgia in the Alleghanies and to Panama in the mountain meadows of the Rockies. The senior author has collected it in District of Columbia, Virginia, Wisconsin, Minnesota, Iowa, North Dakota, Colorado and Utah, and has examples from New York, West Virginia, Kansas, Sierra Madre Mountains and Nepantla, Mexico. Spangberg described it from New Jersey and Georgia, Fowler (as *germari*) lists it for Mexico and Central America. It has not been taken in Florida or in the southern Mississippi valley and will probably be found to be confined to the northern prairie belt with extensions southward in the mountains. The Colorado and Utah examples were found in high mountain meadows with heavy grass covers. The western material is all relatively longer and narrower than that from the humid east.

This species was listed as *melanota* Spgb. in the former review, as at that time no material had been studied (the western material was as yet unmounted) from the Rocky Mountain region or southward and all descriptions from this region were thought to apply to the following species. On restudying these descriptions with the new material it became fairly certain that *unicolor* of Stal. was based on a female of this species without spots on the pronotum and that the species listed by Fowler as *germari* was *unicolor* and not *angulata* as formerly suggested.

Gypona verticalis Stal.

Material of this species is at hand from many places in Colorado and Utah (Ball) New Mexico (Townsend), Arizona (Williams) and from a number of places in Mexico. The synonomy given before appears to be correct and in addition it is probable that *fuscinervis* Stal, which was described from a single male, will be found to belong to this group, in which case the name will take precedence. This species is found in the clumps of Snowberry growing on rocky ridges and warm mountain slopes and is typically arid in its distribution, while on the other hand *unicolor* is found only in the high wet mountain valleys in the arid regions and is typically humid in distribution.

Prairiana cinerea Uhl.

This rusty straw-colored species in its many striking varieties ranges from Massachusetts to California and from Montana to Mexico, but is abundant only in the short grass region and the transition zone to the prairies. Isolated examples have been found in Iowa, Illinois and Connecticut on the east and in extreme southern California and down to Vera Cruz, Mexico on the west. Ball suggested that the Massachusetts reference probably belonged to *miliaris*, but through the kindness of Dr. DeLong, the writers have examined a typical example of var. *kansana* from Connecticut (Garman). The senior author in many years collecting west of the Rocky Mountains only found it in one isolated spot in Southern California. Varieties *kansana* and *subta*, two of the extremes, were the only ones with sufficient material for study, but there was no appreciable difference in their internal genitalia.

P. cinerea var. *moneta* Van D., resembles *kansana*, but is much smaller, narrower, with a long and extremely foliaceous vertex, smoky with the vertex and pronotum paler. This variety seems to be confined to the extreme Southwest. It was described from three females from the Gulf of California and the senior author took two males at Chino, California, in June.

P. cinerea var. *orizaba* nov. var. Still longer and more slender than *moneta*, as long as *kansana*, but much narrower, pale straw with a few elongate dashes around the margins of elytra. Length, 9 mm.

Vertex and pronotum much elongated, over three-fourths of vertex in front of eyes, acutely subangular with the apex rounded. Elytra very long and narrow, pale straw. The vertex and pronotum very finely irrorate with scarlet, a pair of fine fuscous points back of the ocelli and a few irregular linear dashes in the areoles mostly around the margins.

Holotype male Orizaba, Mexico, January 9 to 16, '92 (H. Osborn). Type in senior authors collection. This must also, be a rare form as it does not seem to be listed in the Biologia.

Genus Ponana Ball.

This genus is distinctly subtropical in distribution only one species (*scarlatina*) occurring in the Northern States and then with only 3 or 4 of its numerous varieties. The past two years collecting in Florida has brought together a large amount of material in this group. The internal genitalia of all these forms has been studied and as a result several more forms previously recognized as distinct species have been found to be only varieties of *scarlatina*. On the other hand the new materials has indicated that several more varieties are sufficiently constant and have food plant or environmental factors that warrant their recognition.

KEY TO SPECIES OF PONANA.

A. Vertex moderately long and slightly produced, elytra usually with spots, dots or flecks.
  B. Vertex longer, species variable in color, moderate to large, 1. **scarlatina** Fh.
  BB. Vertex shorter, species small dull gray................2. **curiata** Gib.
AA. Vertex short and very broad, almost parallel-margined elytra with apical and discal cells free from spots or dots.
  C. Pale green with concolorous nervures, often with black along suture, vertex margin thick but definitely produced...3. **dorsalis** Spbg.

CC. Brown with darker nervures, vertex margins rounding broadly to face, ocelli just back of margin.
  D. Nervures lightly, narrowly lined with brown, spots along anterior margin of pronotum........................4. **marginifrons** Fowl.
  DD. Nervures brown, marginal spots on pronotum back of eyes only. 5. **resima** Fowl.

Ponana scarlatina Fitch.

There are a number of additions to the former list of varieties and some consequent regrouping as shown in the following key.

KEY TO THE VARIETIES.

A. Smoky or pale with little trace of red (rare in **puncticollis**), areoles without red flecks and rarely with a few transverse vermiculations.
  B. A smoky median stripe or heavy transverse fuscous vermiculations, without pronotal spots (at most 2). (Northern varieties).
    C. A variable smoky brown median line, few if any transverse vermiculations.
      D. Elytra smoky with only lateral margins pale..1. **limbatipennis** Spbg.
      DD. Elytra with only a narrow median line smoky....2. **pectoralis** Spbg.
    CC. No smoky median line, heavy transverse vermiculate reticulations, 3. **scarlatina** Fh.
  BB. Pale varieties usually with four spots on submargin of pronotum and four on each elytron, two large on claval suture and two smaller on margin in form of pack saddle (mostly Gulf Coast).
      E. Pale brown or with a reddish tinge, spots on pronotum and elytra and some transverse vermiculate lines at least along suture...4. **puncticollis** Spbg.
      EE. Yellowish or greenish varieties, sometimes almost white, no transverse vermiculate lines, pack saddle spots on elytra.
        F. Stout, yellowish, no spots on pronotum........5. **citrina** Spbg.
        FF. Smaller, more slender greenish four spots on pronotum, 6. **meditabunda** Spbg.
AA. Red or red flecked or brownish, with numerous definite dots or spots in the areoles.
  G. Elytra without black spots in the areoles, except for the pack saddle and a few other paired marks, whole insect usually flecked.
    H. Scarlet or testaceous varieties.
      I. Heavily flecked with scarlet, the nervures inconspicuous, 7. **irrorella** Spbg.
      II. Testaceous, the nervures conspicuous, red flecking faint or absent..8. **rodora** Ball.
    HH. Straw colored with faint red flecking giving a reddish tinge, pack saddle marks, the base of appendix and one or two pairs of spots adjoining dark.................................9. **pauperata** Spbg.
  GG. Elytra with numerous black spots in the areoles, a pair of black spots on the pronotum back of ocelli, rarely more than a trace of red flecking.
    J. Ground color scarlet by virtue of inconspicuous red flecking, 10. **sanguinolenta** Spbg.
    JJ. Ground color dirty straw, washed with pale brown.
      K. Spots in areoles inclined to be round and irregularly placed, a single pair of black spots on pronotum back of ocelli, 11. **grisea** Spgb.
      KK. Spots in areoles inclined to be transverse and arranged along nervures, usually a pair of spots on base of vertex, another on pronotum in line with ocelli and two additional pairs, forming a crescent.....................................12. **dohrni** Stal.

The food plants and habitats of the varieties are quite strikingly diverse and suggest that there are at least three groups of species involved. The study of both external and internal genitalia from long series of examples, however, gives no basis of separation and each locality seems to have its own slight variation from the type as well as extremes that intergrade in all directions.

Var. *limbatipennis* has been recorded from Buttercups and *pectoralis*, from Basswood, *scarlatina* has no recorded food plant but has been taken where Basswood and Buttercups were both abundant.

Var. *puncticollis* both nymphs and adults have been taken from Basswood sprouts in deep shady swamp areas in Florida the past year.

Var. *citrina* occurs abundantly in damp shaded areas where the Labiate *Micromeria brownei* forms dense mats. The green nymphs and greenish creamy adults have both been taken from these mats.

Var. *meditabunda* has been taken in low flat pine woods, usually in open grass and swampy areas where the little water pennywort (*Hydrocotila*) is abundant.

Varieties *irrorella*, *rodora* and *pauperata* are all very strictly confined to the mat like areas of the Gopher plum (*Chrysobolanus oblongifolius*) occurring in the high, dry, sandy areas. The difference in color and markings is largely a seasonal effect. The brilliant red flecked *irrorella* is largely a summer form, the dark coppery *rodora* a summer and fall extreme while the pale *pauperata* is the winter and spring form. The nymphs of all these forms are dark red. *G. spadix* DeLong, proved to belong to var. *rodora* on examination of an example kindly sent by Dr. DeLong.

Var. *sanguinolenta* is found both larvæ and adults in the thick mats of the low growing oaks in the higher spots of the flat pine areas.

Var. *grisea* also appears to feed on the low oaks but only where they are in deep shade of the hammock forest type probably a different species of oak as the relative abundance of the species of low oaks is quite different in the two areas.

Var. *limonea* nov. Form and size of *pectoralis*, but entirely lacking the dark markings. Uniform pale tawny yellow, glistening, the eyes and ocelli dark brown, disc of scutellum paler.

Holotype female and paratype female, Vinton, Ohio, June 5, 1900 (Osborn Collection).

Allotype male and paratype female, Washington, D. C. (Ball Collection).

After the completion of this paper Doctor Osborn sent a large tawny yellow female that at first sight was mistaken for *Gypona unicolor*, but on examining the vertex margin it proved to be a *Ponona* and evidently the pale extreme in the *limbatipennis-pectoralis* group. The more tawny examples of *citrina* are similar in color, but the thickening of the apex of the head will at once separate them.

Ponana resima Fowl.

This species occurs abundantly on the mat forming oaks and both nymphs and adults are occasionally found on practically all .species of oak. The nymph is easily recognized by its blunt head, alternate red and green bands and the presence of silver scales on the dorsum.

THE NYMPHS

The generic characters in the nymphs are as definite and constant as those in the adults, *Xerophloea* nymphs have an even larger and more foliaceous, angularly pointed, head than the adults and a similarly tapering body. *Gyponana* nymphs are green, flat with long foliaceous vertices that are definitely narrowed immediately in front of the eyes. The antennæ are extremely long and thread-like. *Gypona* nymphs are heavy bodied with long vertices that are thickened slightly at the apex. The antennæ are shorter and the bristles on the body sparse but strong. *Prairiana* nymphs are dirty rusty straw colored usually dotted with black. They are almost parallel margined with very long foliaceous heads. The eyes are very small and set into the posterior part of the margin. The front is very long and narrow, the antennæ short and the first three segments large. *Ponana* nymphs are red or reddish green, short and stout bodied with relatively short rounding vertices. The front is broad, the antennæ short and the hind legs extremely broad and bowed. *Penthimia* nymphs are red and even shorter and rounder than those of *Ponana* with heavily overhanging vertex margins. The abdomen is shorter than the thorax.

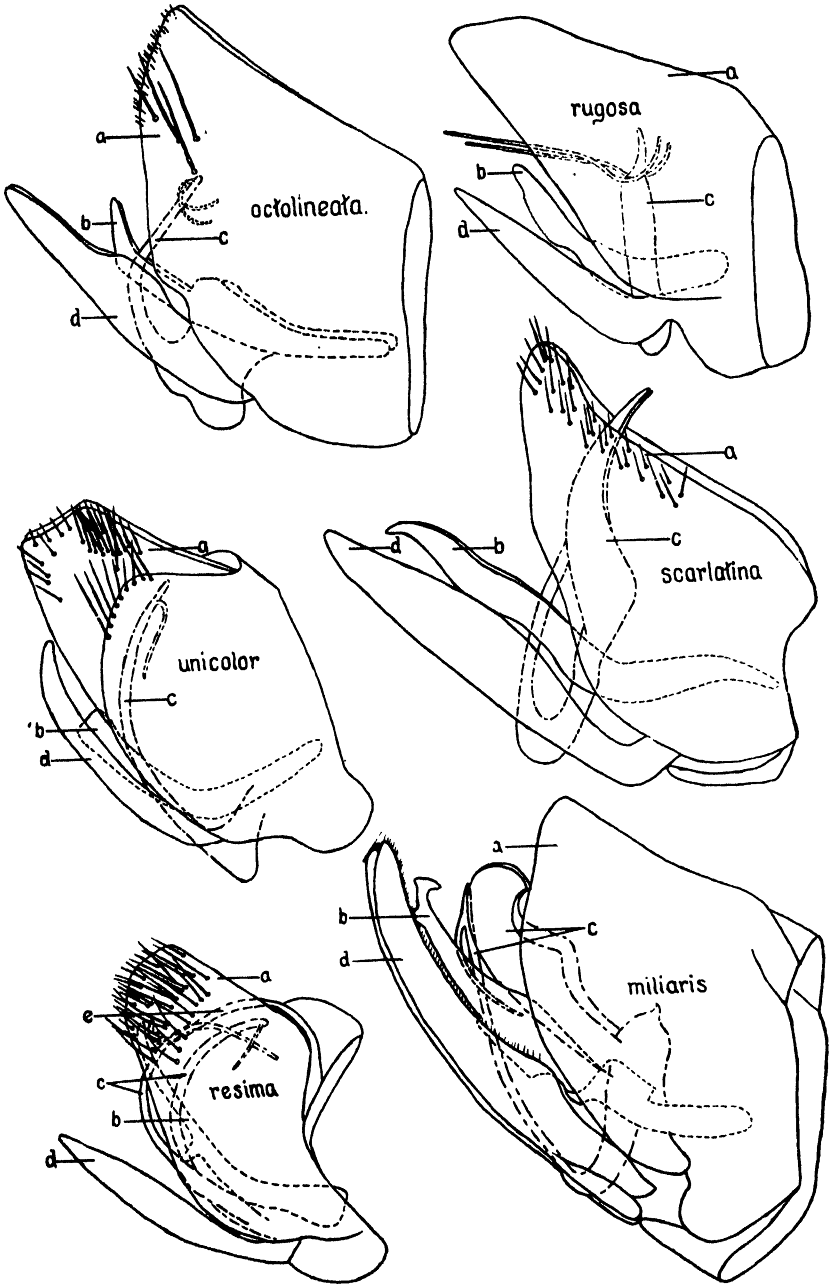
EXPLANATION OF PLATES.

PLATE XXV.

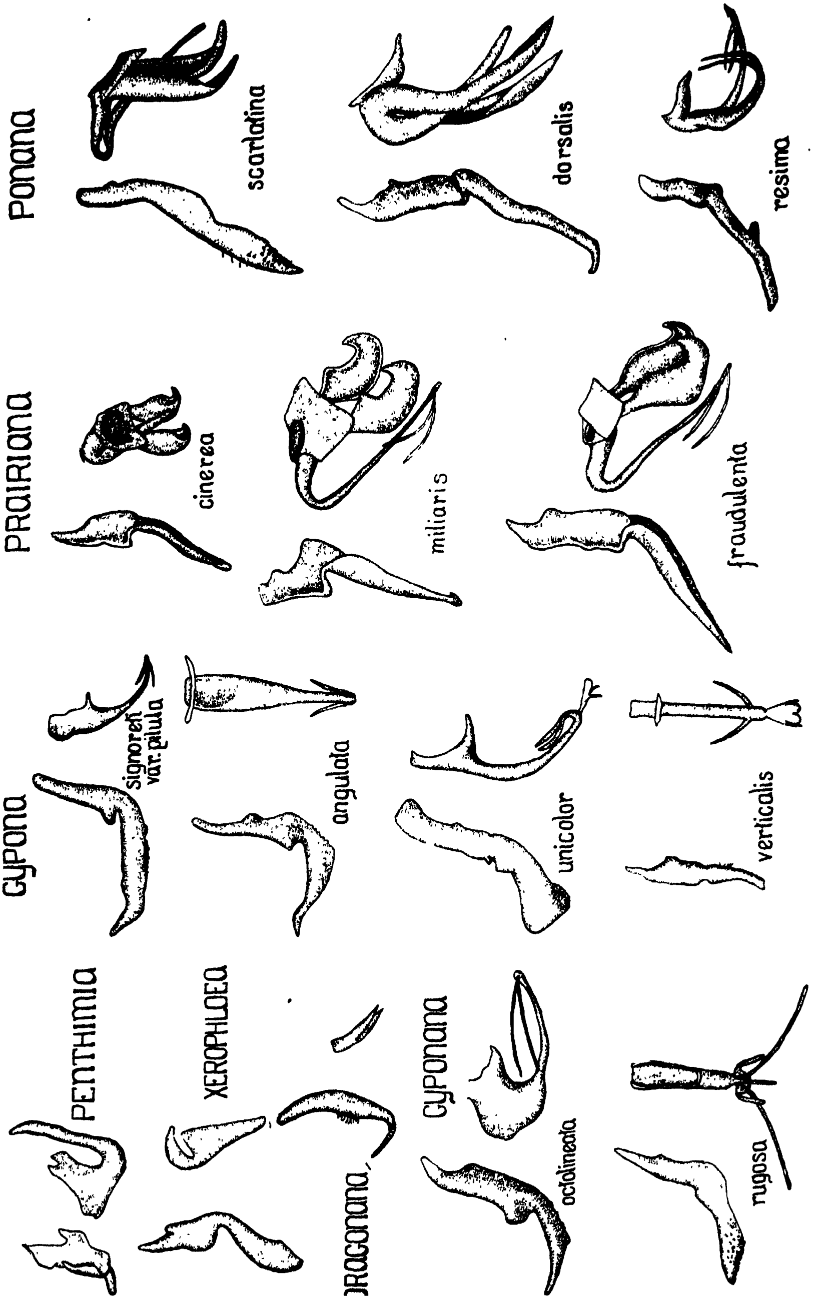
Internal Genitalia of typical species of each genus in situ. a, Pygofer; b, Styles; c, Oedagus, d, Plates; e, Pygofer spine.

PLATE XXVI.

Showing style and oedagus of each species arranged by genera. The style is on the left and the oedagus on the right. The oedagi except in ***rugosa*** and ***angulata*** viewed from the side. All drawings made to the same scale from cleared and dissected material in permanent balsam mounts with the cover glass pressed down.



Bell and Reeves.



Ball and Reeves

THE APPLICATION OF STUDIES IN HYDROGEN ION CONCENTRATION TO ENTOMOLOGICAL RESEARCH.

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INTRODUCTION.

In all living matter biochemical reactions within and without the cell are continually influenced by hydrogen and hydroxyl ions which have, therefore an important significance in all biological studies. Although this phase of investigation upon insects has hitherto received little attention, there are many problems in which a knowledge of the concentration of these ions is of significance in entomological research. A few typical examples may be cited to indicate the relationship.

Many injurious species of insects of economic importance pass at least part of their development in a soil medium, the pH of which plays an important role in development of the insect and incidentally in control. The application of studies in hydrogen ions to life-history work in general will lead to a greater insight into the process of growth and development. Moreover, a better understanding of host preferences may be gleaned as a result of studies of the pH of the body fluids of insects and of the host plants upon which they feed. Of paramount importance in preventing injury to susceptible plants is a knowledge of the pH of arsenicals and other substances used as sprays. In studying the effect of arsenicals or other substances upon insects, the control of the pH of dilutions used in the experiments is essential in order to eliminate the influence which the H or OH ions may have upon insects. Studies on digestion and nutrition require a knowledge of the pH of the alimentary tract. In all biological work problems constantly arise that invlove a knowledge of the absolute effects of these ions as they exist in various solutions.

It is quite evident from the few examples cited that studies in hydrogen ion concentration should become part of many biological investigations in entomological research.

METHODS FOR DETERMINING HYDROGEN ION CONCENTRATION IN SMALL QUANTITIES OF FLUID.

THE INDICATOR METHOD.

Unfortunately the quantity of fluid available for study in single insects is usually of the magnitude of about 0.01 cc, equivalent to a medium-size drop, though in certain stages of insects, as the larvæ of most species and in the adults of certain *Orthoptera* and *Coleoptera*, it may be possible to obtain several drops of fluid. On the other hand it is quite impossible to obtain even a drop of fluid from the adults of most *Lepidoptera*, *Diptera*, and *Hymenoptera*.

With so little fluid available it has, hitherto, been out of the question to utilize the potentiometer method for pH measurements, and several investigators when dealing with minute amounts of fluid have utilized the indicator method described by Felton (3) and others. This method has been found very convenient by the writer for obtaining approximate results, and in principle consists in comparing the color produced by an unknown drop of fluid to the colors in a series of known drops of buffer solutions having definite pH values to which a drop of some indicator had been added. The accuracy of this method is within 0.1 to 0.2 pH, which for ordinary purposes is quite sufficient.

The equipment necessary for the indicator method is very inexpensive and consists of the following: (1) an opal glass plate, (2) a set of standard buffer solutions, (3) a set of indicators, (4) several stirring glass rods. These may be obtained from any chemical firm. Buffer solutions may be purchased in definite pH units or as a Universal Buffer Solution and dilutions made up according to the series of pH units desired. The writer found the latter method expedient and more desirable, since if by chance a buffer solution should become contaminated or if additional units were needed during the progress of some investigation these could be made without loss of time. If the latter method is adopted it is essential that the buffer solutions be placed in 30 cc. stock bottles fitted either with ground-glass pipettes or with Barnes pipette stoppers. This equipment insures a pipette with each buffer solution delivering drops of equal volume. The indicator solution should be stored in similar type bottles to deliver uniform drops. The indicators recommended by Clark (1) and Clark and Lubs (2) can be purchased as powdered dyes and the solutions made according to the directions given by the above authors, or the indicators may be purchased in solution ready for use. The following indicators were found useful in ordinary work encountered in entomological research: Brom cresol green (pH4—5.6), brom cresol purple (pH 5.2—6.8), brom thymol blue (pH 6.0—7.6), and phenol red (pH 6.8—8.4).

Method of Procedure.

The procedure in determining the pH of an unknown solution is as follows: A series of drops from standard buffer solutions having a wide range of pH, as, for example pH 4, 5, 6, 6.8, 7 and 8, are placed upon an opal glass plate, and to each of these is added a drop of indicator having the same range of pH as the buffer solution, and the drops are mixed by means of the glass rods. A series of drops of the unknown are similarly arranged in a row, each receiving a drop from a different indicator, and mixed by means of the glass rods. The resulting color of the unknown is then matched against the colors produced by the known buffer solutions. This procedure serves as a "feeler" for determining the approximate pH of the unknown. The next step is to make a closer and more accurate determination of the pH of the unknown by comparing to buffers in units of 0.1 pH. After several trials in comparing colors it becomes comparatively a simple procedure to determine the pH of the unknown.

The simplicity of the indicator method favors its adoption as a field method for entomological work of the kind outlined above. Unfortunately the blood of many species of insects is highly pigmented and the color in many instances interferes with the pH determinations by the indicator method. Felton, however, recommends the use of stronger indicator solutions when dealing with colored or turbid fluids. This may be of advantage for certain types of work. If, however, difficulty is experienced in obtaining consistent results, resort must be had to the potentiometer method.

Ordinary sanitary precautions are to be observed when dealing with the indicator method. The drops of fluid for comparison should be of the same volume, and the glass rods

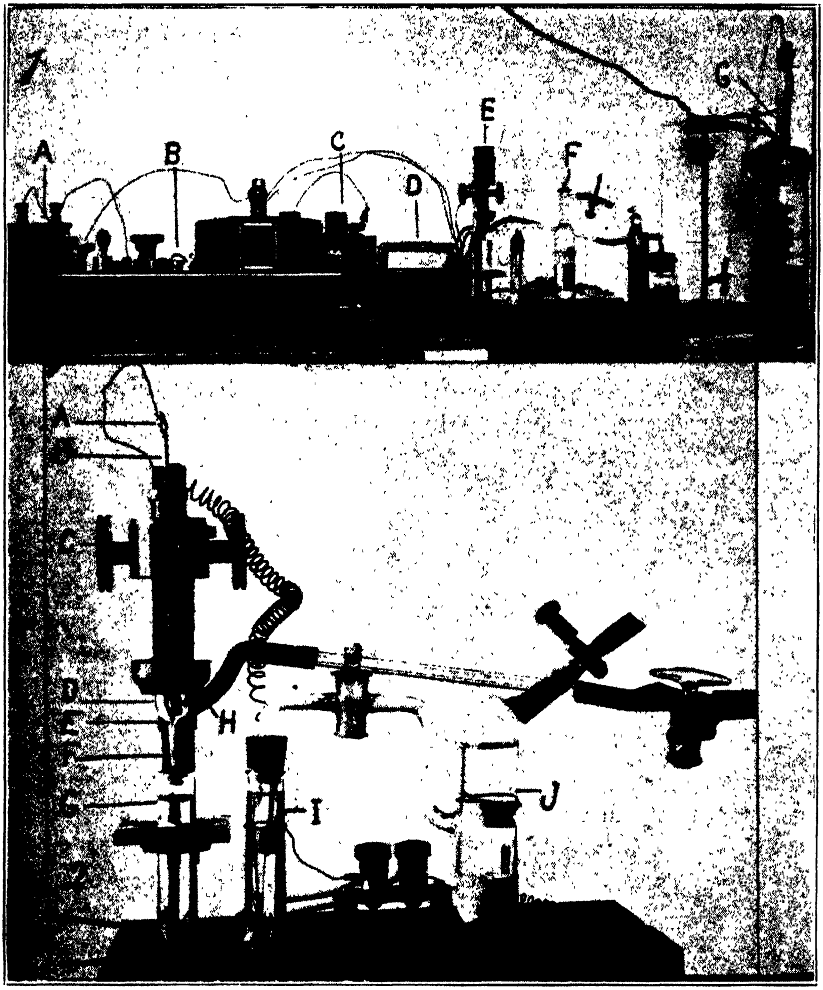

FIGURE I

(1.) Assemblage of apparatus for the electrolytic determination of the pH of the blood of insects. A, standard cell; B, potentiometer; C, 4-volt battery furnishing the E. M. F.; D, galvanometer; E, modified microscope in which is mounted the electrode vessel containing the platinum electrode; F, the calomel electrode; G, the hydrogen generator.

(2.) Electrode vessel mounted on a modified microscope and calomel electrode connecting with the KCL solution in the U tube, all mounted on a wooden base. A, copper wire connecting by mercury with electrode; B, capillary glass tube holding the platinum electrode; C, coarse adjustment for lowering or raising the electrode vessel; D, the glass vessel; E, platinum electrode; F, capillary tube for testing fluid; G, U-tube of saturated KCL bridge; H, arm fused on side for hydrogen intake; I, arm for calomel electrode connecting with the KCL bridge; J, calomel electrode.

used for mixing the solutions should be cleaned to prevent contamination of one solution with another. It is also necessary to make the determinations very quickly to minimize exposure of the unknown to the influence of the carbon dioxide of the air, as the exchange of gases takes place rapidly on exposed surfaces.

THE POTENTIOMETER METHOD.

The large number of books published on the subject of hydrogen ion concentration and the many bulletins issued by makers of potentiometer apparatus explain this method in detail. It will be necessary, therefore, only to point out the improved hydrogen electrode vessel described by Bodine and Fink (4) for the purpose of making the potentiometer available for the pH determination of minute amounts of fluids.

The entire apparatus assembled for the purpose of hydrogen ion measurements is shown in Figure I (1) and consists of potentiometer, standard cell, 4-volt battery, box galvanometer, dry cells, hydrogen generator, and the modified hydrogen electrode vessel mounted in the tube of a modified miscroscope with the calomel electrode and KCL bridge all held rigidly in a small wooden base. An enlargement of the hydrogen electrode vessel and calomel electrode mounted on the wooden base is shown in Figure I (2). The electrode vessel is shown mounted in a modified tube of the microscope, the capillary part of the vessel contains the fluid to be measured and by means of rack and pinion the entire vessel with capillary may be lowered into the saturated KCL solution in one arm of the U tube. An extension from the calomel electrode fits into the other arm of the U tube. Passing through the hydrogen electrode vessel is a capillary glass tube with sealed platinum wire—the platinum electrode. This tube is filled with mercury. Both the hydrogen electrode vessel and platinum electrode are so adjusted that the platinum point is exactly centered and can be raised or lowered, making contact with the surface of the fluid in the capillary. Wires from both the calomel and platinum electrodes lead to the potentiometer and the potential difference of the fluid in the capillary portion of the vessel is read in millivolts on the potentiometer and calculated in pH values.

To determine the hydrogen ion concentration of the body fluid of an insect, for example, a puncture is made mid-laterally by means of a needle and the drop of fluid that oozes out is held against the tip of the capillary and sufficient fluid is drawn up to fill the capillary. In some species by cutting off a leg or a wing sufficient fluid is obtained to fill the capillary. By means of the platinum electrode that passes through the electrode vessel, contact with the surface of the fluid in the capillary is made; and by means of rack and pinion the electrode vessel is lowered and contact established with the KCL solution in the U tube. These contacts close the circuit of the system, and the potential difference of the fluid is read on the potentiometer. Of course, previous to determining the pH of any unknown fluid, it is essential to have the potentiometer in perfect balance with the standard cell, and to check the platinum electrode with a standard buffer solution.

After each reading, the fluid in the capillary is drawn off by means of filter paper held against the tip of the capillary which is afterwards flushed several times with distilled water and hydrogen. Between readings it is advisable to use some standard buffer solution in the capillary to test the sensitivity and accuracy of the platinum electrode.

Precautionary Measures.

Several precautionary measures are to be considered to avoid difficulties in manipulation and to obtain consistent results. The platinizing of the platinum electrode should be prepared as explained by Michaelis (5) and when not in use this should be kept in pure water. The electrode vessel should receive a steady flow of pure hydrogen from the generator to maintain a definite positive pressure, and prevent diffusion of fluid from the saturated KCL solution. If difficulty is experienced in obtaining a perfect balance with the standard cell, the battery furnishing the E. M. F. probably needs recharging. The platinum electrode should be perfectly centered and not touch the sides of the electrode glass vessel, otherwise readings will vary and a lag follow. In cleaning and dislodging bubbles of air in the capillary, the use of a fine wire will be found useful. For other precautions see Clark (1), and Bodine and Fink (4).

EXPERIMENTAL RESULTS.

From the many problems in hydrogen ion concentration outlined previously that need to be investigated, an attempt has been made, first, to determine the reactions of the body fluids in a large number of species of insects belonging to several orders; secondly, to determine the relative changes, if any, in the hydrogen ion concentration that may occur during development of an insect from the egg to the adult form. All the pH measurements recorded in this paper were made by means of the potentiometer.

TABLE I. THE pH OF THE BLOOD OF INSECTS BELONGING TO THREE ORDERS.

Species	Average pH
Lepidoptera. Average pH 6.53.	
Pieris rapæ L.	6.64
Autographa brassicæ Riley	6.55
Malacosoma americana Fab	6.50
Heliothis obsoleta Fab	6.56
Datana ministra Dru	6.35
Agrotis ypsilon Rott	6.60
Coleoptera. Average pH 6.85.	
Cotinis nitida L.	7.14
Popillia japonica Newm	6.85
Pheletes agonus Say	6.91
Leptinotarsa decemlineata Say	6.62
Harpalus caliginosus Fab	6.89
Harpalus pennsylvanicus DeGeer	6.90
Tenebrio molitor L.	7.00
Diabrotica 12-punctata Fab	6.50
Orthoptera. Average pH 7.10.	
Melanoplus femur-rubrum De Geer	7.02
Melanoplus differentialis Thos	7.11
Dissosteira carolina L.	7.25
Microcentrum retinerve Burm	7.07
Gryllus luctuosus Serv	6.94
Concephalus brevipennis Scudd	7.15

Data for the first problem were obtained upon a large number of individuals belonging to a species and the results averaged as shown in Table 1. In general there are slight differences in hydrogen ion concentration between species, but the general average for an Order gives results that indicate that the hydrogen ion concentration of species belonging to *Lepidoptera* is higher than for the species belonging to the

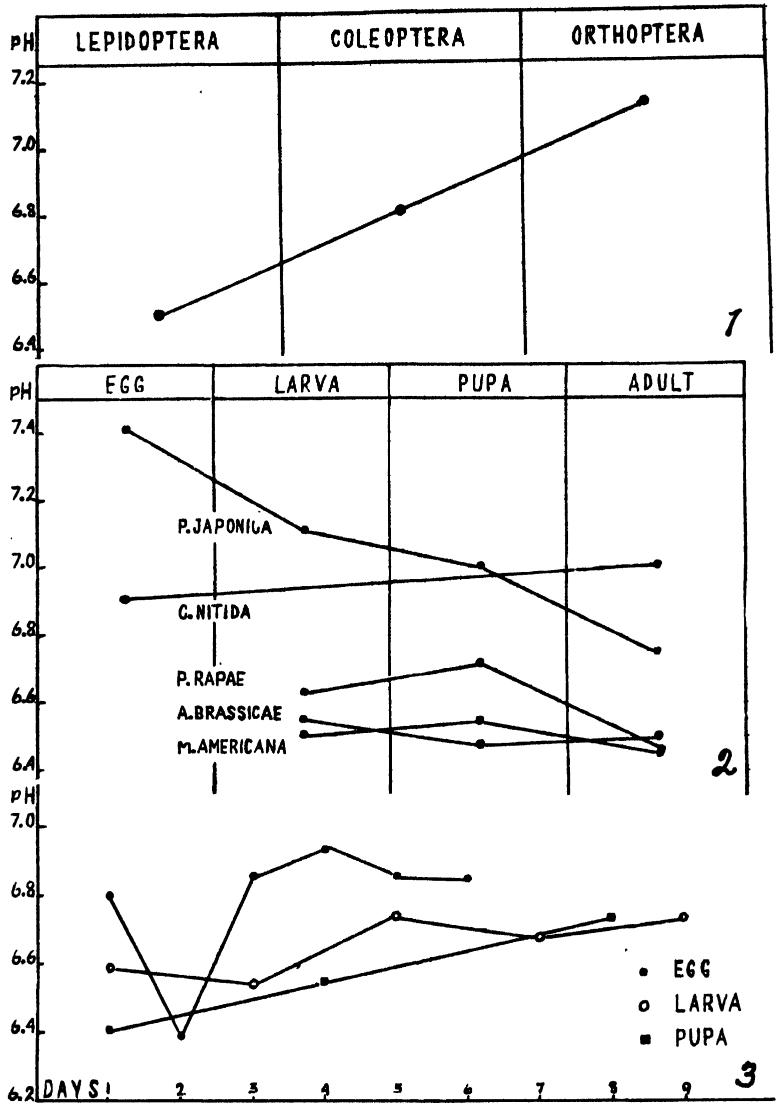

FIGURE II

(1.) Average pH of the blood of species belonging to three orders. Species of the order Lepidoptera indicate a higher hydrogen ion concentration than the species belonging to the orders *Coleoptera* or *Orthoptera*.

(2.) Average pH of the blood of various stages of species belonging to the orders *Lepidoptera* and *Coleoptera*. This figure shows that in nearly every stage of development of *Lepidoptera* the hydrogen ion concentration is greater than is the case with species belonging to the order *Coleoptera*.

(3.) Changes in pH that occur during development of the potato beetle (*Leptinotarsa decemlineata*) from the egg to the adult. Each point is the average of many determinations.

Order of *Coleoptera* or that of *Orthoptera.* From the results indicated graphically in Figure II (1–2) it is quite evident that this relationship seems to hold even for different stages of the species; that is, an acid medium for species belonging to the Order *Lepidoptera*, a less acid medium for species belonging to the Order *Coleoptera;* and a neutral medium or slightly alkaline for species belonging to the Order *Orthoptera.* Whether such a relation will continue to be maintained when data for a large number of species belonging to many Orders will become available, remains to be determined.

For the second problem the change in hydrogen ion concentration that may take place during development of an insect from the egg to the adult was determined on the potato beetle, *Leptinotarsa decemlineata* Say. The method adopted was to obtain daily pH determinations on a large number of eggs from the time they were first deposited until they hatched. Measurements of the pH of the body fluids of larvæ were made upon a large number of individuals representing each stage of growth. Determinations of the pH of the body fluids of pupæ were made upon a large number of individuals on the first, fourth, and last days of development. The results have been averaged and are indicated in Table 2 and plotted in Figure II (3).

TABLE 2. THE pH OF THE BLOOD OF THE POTATO BEETLE (LEPTINOTARSA DECEMLINEATA) DURING DEVELOPMENT.

EGG		LARVA		PUPA	
Days	Aver. pH	Days	Aver. pH	Days	Aver. pH
1	6.79	1	6.58	1	6.42
2	6.36	3	6.52	4	6.59
3	6.85	5	6.74	8	6.72
4	6.95	7	6.64		
5	6.82	9	6.71		
6	6.95				

From this figure it is observed that although the initial pH of the egg on the first day is 6.79, it becomes on the second day more concentrated in hydrogen ions (pH 6.36) and in subsequent days the hydrogen ion concentration becomes less. Concerning the higher concentration of hydrogen ions that occur on the second day, one explanation might be the well known fact that in its earlier stages the egg consists almost entirely of yolk. The splitting and breaking down of this fat material into fatty acids produce an acid medium. Whether in the upbuilding of the embryo the energy liberated in the breaking down process is utilized, is not known.

There appear but slight changes in the hydrogen ion concentration during larval development; first, second, third, and fourth larval stages give an average pH of 6.58; 6.52; 6.74; and 6.64, respectively, and the average pH of the body fluids of the larvæ as they enter the ground before pupation is 6.71.

Changes in hydrogen ion concentration of pupæ are rather more marked as indicated in Table 2 and Figure II (3). Furthermore, there is a well marked difference between the pH of the larvæ as they enter the ground for the purpose of pupation (pH–6.71) and that of the pupæ that are first formed (pH 6.42). As pupal development continues, however, the hydrogen ions become less concentrated until at the termination of pupal development a pH of 6.72 is obtained.

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THE THERMOCOUPLE METHOD OF DETERMINING TEMPERATURES.*

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USES AND ADVANTAGES.

The thermocouple is used in many different fields for the determination of temperatures. Physicists first employed this method in 1812, but at that time the process was a slow and tedious one. With improved apparatus the method became more practicable, and during recent years it has come into wide use both in the exact sciences and in the industries.

In biology the thermocouple method is also coming into more frequent use. It is very well adapted to entomology, and in fact there are occasions when temperatures cannot be taken practicably by any other means. With this method it is possible to determine temperatures of places which are otherwise inaccessible, as in an atmosphere of poisonous gas when fumigating, or in the soil, water or under the bark of trees. The internal temperature of insects under various conditions may also be found.

When the couple is placed in position, readings of any number of points may be taken quickly, and this may be continued over an extended period without disturbing the situation. The location, also, may be practically any distance away.

The thermocouple permits extreme accuracy, for with its accessory parts it forms an instrument of high precision and gives readings correct within one twenty-fifth of a degree if this is desired. An accuracy of one one-thousandth of a degree may be obtained but this requires especially sensitive equipment and is beyond the scope of the present article.

A very rapid response to temperature changes is characteristic of this method for the couple shows instantly any change large or small. This is necessary on such occasions as when recording heat of crystallization during freezing-point determinations. Another advantage is that temperatures are very distinctly indicated; and the galvanometer may be made so sensitive that a change of one degree in temperature will have a range of one inch or more on the scale.

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The thermocouple system is simple and easy to operate and the accessory apparatus required is not unduly expensive. Probably if more were known about the subject it would lead to a greater use of this method in entomology. Following is a non-technical statement of the principles involved and the method of construction and operation.

The Principle of the Thermocouple.

If wires of any two dissimilar metals, copper and nickel for instance, are joined end to end, two connections called "thermo-electric junctions" will be formed as at A and B in Figure 1-a.

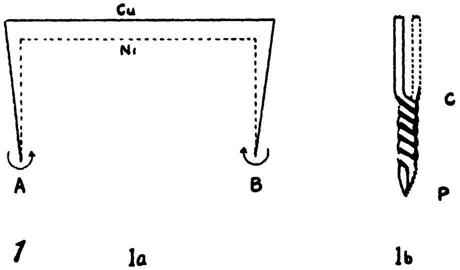

Fig. 1. 1-a, Two thermo-electric junctions.
1-b, Detail of junction.

These junctions are so named because when the two different metals are joined together a flow of electrons will take place from one metal to the other, in this case from copper to nickel. This flow of electrons results in a force called an "electromotive force" (e.m.f.) being set up at each junction; and the magnitude of this force *depends on the temperature.* If the temperatures of the two junctions are equal the e.m.f. will also be equal; and since the flow of electrons is from copper to nickel, as shown by the arrows in Figure 1-a, the two forces will be opposed to each other. Consequently there will be no current in the circuit. However, if the temperatures are different there will be a greater e.m.f. generated at the warm junction (with metals used in biology) resulting in a current around the circuit. The energy necessary to maintain the current is derived from the excess heat absorbed by the warm junction.

The current depends, therefore, upon a difference of temperature being maintained between the two junctions. The cold junction is kept in a known and constant temperature as in a mixture of ice and water in a thermos bottle, which can be held for hours at 0° C. The warm junction is then placed in contact with the material the temperature of which is to be determined. Since one temperature is known, and since the e.m.f. generated in the thermocouple depends directly upon a difference in temperature between the two junctions, the unknown temperature can readily be determined.

THE PRINCIPLE OF THE POTENTIOMETER AND THE PYROVOLTER.

In actual practice the unknown temperature can be ascertained very quickly by a few simple movements. However, it is usually well to know a little about the instruments used and the principles involved. The e.m.f. generated in the thermocouple can be measured in two ways: by the galvanometer and the potentiometer methods. The former measures the current direct and is the simpler method, but it involves certain errors due to the resistance of the lead wires, which resistance varies with the length and diameter of the leads. Errors also come in because of differences of temperature through which the leads pass.

Fortunately these errors are eliminated in an ingenious and satisfactory manner by the use of the potentiometer. With this instrument only the e.m.f. of the couple *and not the current* is measured. Consequently the leads (which are the copper wires connecting the junctions with the potentiometer) may be of any length and diameter and may pass through any variations of temperature without affecting the accuracy of the readings. In order to measure this e.m.f. it is balanced against a variable "difference of potential" (d.p.) in a circuit within the potentiometer, and the d.p. is known by means of a "standard cell."

A very compact and portable instrument results from a simplification of this method. It embodies what is called the pyrovolter principle where the use of the standard cell is avoided. By simply turning a knob until the galvanometer points to zero, the e.m.f. of the couple is first balanced against the d.p. of a fixed resistance within the instrument. Then with a second movement the connections are so changed that the galvanometer is inserted into the main circuit. A deflection is at once produced within the galvanometer and it indicates two things at the same time. It indicates first the d.p. which balanced the e.m.f. of the couple because the deflection is produced by the identical current that previously had produced the d.p. Secondly it indicates the temperature of the warm junction because the magnitude of the e.m.f. is dependent upon temperature difference, and the scale is marked to show degrees of temperature.

SIMPLICITY OF THE THERMOCOUPLE METHOD.

Although it may appear at first glance to be rather complicated, this method is in reality quite simple and rapid, due largely to the excellent equipment now available. Complete outfits for this work may be obtained from various makers of scientific electrical equipment. The instrument embodying the pyrovolter modification is so constructed that it contains all the necessary parts for the work, except the outside galvanometer; and it is very satisfactory for use in biological work. When making the determination the two leads from the thermocouple are connected to the pyrovolter, through the outside galvanometer; the balancing e.m.f. is obtained by turning knob R, Figure 2, until the galvanometer points to zero; then a button is pressed and the deflection instantly indicates the desired temperature.

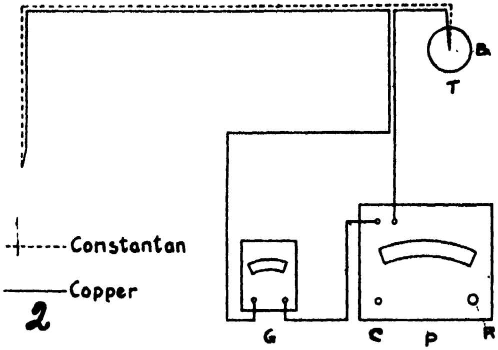

Fig. 2. Method of connecting couple for a single assembly.

CONSTRUCTION OF THE THERMOCOUPLE.

The type of thermocouples required in biological work can be made very easily; and although couples for a great variety of purposes may be purchased complete from the various scientific electrical instrument companies, it is well to know how to make them in the laboratory. For the range of temperatures with which biologists are concerned the two metals used are copper and constantan. The latter is an alloy of 60% Cu and 40% Ni. Wire of these metals may be purchased in a number of gages and with silk, cotton or enamel insulation. Number twenty-eight gage has been found by the writer to be preferable for most purposes, and enamel insulation to be the most satisfactory.

A length of constantan wire, equal to the distance between the thermos bottle and the point where the temperature is to be determined, is taken together with a length of copper wire one foot longer. The insulation is removed from the ends for about one-half an inch; then one end of each wire is wound around the other as shown in Figure 1-b. The junction is next evenly soldered from the tip to the point of separation. A good method is to melt a little self-fluxing solder, as used in radio work, upon a clean side of a soldering iron and then to immerse the junction in the lead from C to P, Figure 1-b. This is to be the warm junction. The other end of the constantan wire is soldered in a similar manner to a piece of copper wire about twelve inches long; and this provides the cold junction. A thermocouple is then completed for a single assembly, Figure 2. If the object is to pierce the body of an insect to determine its internal temperature, the tip of the warm junction should be pointed by rubbing it lightly with a fine file, emery cloth or sandpaper, preferably under a pair of binocculars.

A small amount of surgeon's adhesive tape wound between and around the wires of the warm junction will give rigidity to the wires and serve as a handle if such is desired. The silk or cotton insulation of these fine wires soon wears off; therefore if that kind is used, coating it with a substance like shellac or quick drying varnish or enclosing the wires in a rubber tube is recommended to prevent short circuits. Enamelled wire does not require this treatment.

Two holes should be bored in the cork of the thermos bottle, one to hold a thermometer and the other to admit the thermocouple junction. This junction may be lowered directly into the ice and water, but it is much more preferable to enclose it in a piece of glass tubing, one end of which has been previously fused solid in a flame. After the point has been pushed down into the tube to the bottom the space in the tube should be filled with cotton to prevent air currents which would otherwise affect the temperature at that junction.

SINGLE AND MULTIPLE THERMOCOUPLES.

For determinations of only one unknown temperature, the arrangement shown in Figure 2 will be satisfactory. The junction A is the one to be inserted in the material. B is the cold junction in the thermos bottle T. The copper leads from the two junctions are connected to the potentiometer P and the outside galvanometer G. This latter instrument is strongly recommended in biological work for accuracy in determining when balanced conditions have been obtained. That is, when sufficient d.p. from the potentiometer has been opposed to the e.m.f. of the couple the outside galvanometer will point to zero; and not until that time should the temperature be taken. The distance from A to B may be any length required. The constantan wire in all the diagrams is represented by the broken line and the copper by the full line.

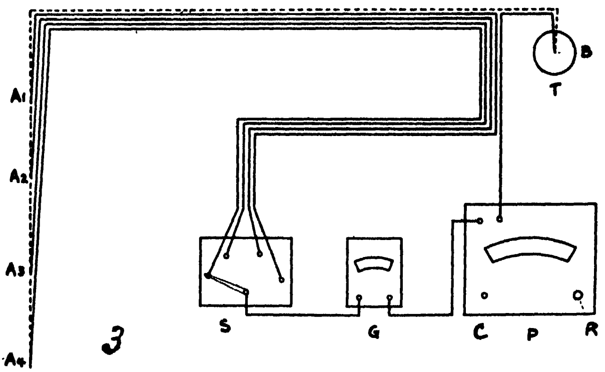

Fig. 3. Arrangement for multiple assembly with warm junctions in linear order.

Frequently it is necessary to determine temperatures of two or more places without removing the junctions. It is quite feasible to do this and to take the readings over an extended period with only a slight modification of the couple. Two types of multiple couples may be constructed very easily. The one shown in Figure 3 is designed for use when the junctions are to be placed one after the other in a continuous arrangement.

Frequently it is necessary to push the couples into a mass of material and this can be done by using a metal pipe. The wires, unless enamelled, should be throughly insulated with shellac or varnish and the system tested before being drawn into the pipe. The junctions should always be insulated with electrician's tape or other material to prevent short circuits with the metal pipe. Air circulation within the pipe should be cut off, as previously mentioned, and this can be done easily by drawing into the pipe along with the thermocouple a cord with plugs of cotton placed in position two or three inches from each junction.

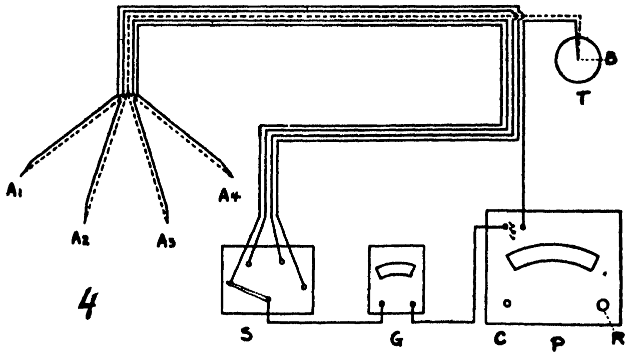

Fig. 4. Arrangement for multiple assembly with warm junctions scattered.

This particular arrangement records the temperature of the air around the junctions, and the air is affected by the temperature of the pipe in contact with the material to be tested. It is therefore merely a matter of each junction coming into equilibrium with that material. It is a comparatively slow process but is quite suitable for some purposes where the temperatures are to be taken over an extended period.

If the locations are accessible this type of couple may be installed by hand and not enclosed in a tube or pipe. It will then give instantaneous readings of temperature.

The other kind of multiple couple, as shown in Figure 4, is made with separated junctions, for use especially where the locations are scattered in various directions. The branches of constantan wire may be soldered to the main constantan wire at any desired or convenient place. The rotary switch S, Figures 3 and 4, is recommended. The plugs on the switch are numbered, and when the lead or copper wire from each junction is connected to its assigned plug, then individual readings can be taken very quickly; for only one junction can be in circuit at any one time, the others are brought in at will by moving the switch over the plugs.

PRECAUTIONS.

Since this apparatus is exceedingly sensitive to temperature and will record very minute changes, it requires corresponding care when using it. Certain precautions are necessary, therefore, in order to get accurate and reliable results.

When about to use the apparatus, the accuracy of the assembly should be checked up by taking the temperature of, say, a bottle of water of known temperature. This has been found better than reading the temperature of the air. It is well to have a bottle of water for this purpose permanently in the laboratory, fitted with a cork and thermometer.

The outside galvanometer should always point to zero when not in circuit. Therefore before using it should always be checked up and if necessary adjusted to read zero.

If the junction has been used for piercing moist tissue, it should be cleaned after each determination by dipping it first in alcohol to remove water soluble material and then in ether to remove fats and alcohol. This is especially necessary when taking freezing-point determinations.

The temperature of the water in the thermos bottle should be carefully watched. The cork should have two holes, one to admit the junction and the other a thermometer. The bulb of the thermometer and the end of the junction should rest in the water at the same depth.

It should be remembered that the e.m.f. of the junction is set up *at the point of contact*, and that this point is where the metals come together, namely at C, Figure 1-b, and not at the tip P. The length CP is merely to give strength to the junction and for convenience in piercing. Therefore in taking readings it is essential to have the point of contact C well within the material.

As soon as the reading has been taken the knob R should be turned back to cut off the current from the battery. If the knob is left turned on indefinitely the battery will be unduly weakened.

PROCEDURE IN MAKING A TEMPERATURE DETERMINATION.

The cold junction is placed in the thermos bottle filled with ice and water. The outside galvanometer is adjusted, if necessary, to read zero when at rest. The thermocouple is connected as shown in the diagram. The warm junction is placed in the bottle of water to check up on accuracy of set-up. The junction is quickly dried by dipping it in alcohol.

Up to this point the procedure has been preliminary to the temperature determination and, of course, it is necessary only when commencing operations. From this stage any number of determinations may be made quickly and simply as follows: Place the warm junction in the material to be tested and it will be observed that the outside galvanometer is immediately deflected from zero. Then turn the knob R forward until the galvanometer again points to zero, press down the button C and read the temperature indicated on the pyrovolter scale. Turn back the knob R.

SUMMARY.

Some of the uses and advantages of the thermocouple method of determining temperatures are discussed, together with an outline of the principles involved. Detailed instructions are given for making thermocouples in the laboratory. The method of procedure in taking a reading is described and certain precautions are suggested in the use of the apparatus.

THE DEVELOPMENT OF THE PROVENTRICULUS OF PITYOGENES HOPKINSI SWAINE.

By James A. Beal, M. S.

Introduction.

The object of this paper is to describe the changes which take place in the proventriculus, of the bark beetle *Pityogenes hopkinsi* Sw. during the period of growth and development from early larval through pupal and adult stages respectively.

The proventriculus is a portion of the alimentary canal lying just anterior to the ventriculus or true stomach which in the adult bears on its internal surface a complicated apparatus consisting of teeth, grinding plates, and straining brushes. This is a chitinous structure, a secretion of the alimentary canal, located in the prothorax. Its function is probably the breaking up, grinding and straining of food which has been taken in by the insect.

A knowledge of this organ has considerable value in taxonomy. The characters of the proventriculus have been discussed in papers by Lindeman, Verhoeff, Sedlaczek, Nusslin, Fuchs, Hopkins, Swaine, and others; and these characters have been employed in arranging keys for determination of genera and even of species. Swaine* says, "I have found internal characters, especially of the proventriculus, of the greatest interest and of much practical value; but a wider study is apparently necessary, employing many genera and species, particularly many specimens in each species, before definite conclusions can be drawn."

The proventriculus is very complicated in structure and its development presents an extremely interesting problem from the standpoint of pure science. Doctor Otto Nusslin† is the only author who has ever described, even in a general way, the development of the proventriculus of any species of bark-beetle. The work which he did on this subject can be found in a German scientific publication. He describes in a very general way the development of this organ, using, to illustrate his descriptions, six original photomicrographs of four stages in *Ips typographus* and two of *Ips acuminatus*. Doctor E. P. Felt* shows, in Memoir VIII, N. Y. State Museum, two photomicrographs of *Pityogenes* sp. in the adult stage.

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*Swaine, J. M. 1918. Canadian Barkbeetles, Part II, page 34. Bull. 14, Dominion Depart. Agri.

†Nusslin, O. "Phylogenie und System der Borkenkafer." Zeitschrift fur wissenschaftliche Insectenbiologie, Vol. 7, 1911.

This problem, then, is one to which very little attention has been paid but which offers much of interest in the way of further study. The reason for selecting this particular species, *Pityogenes hopkinsi*, was because its life history and the methods of rearing this beetle under artificial conditions have been accurately worked out by Doctor M. W. Blackman.† It responds quickly to artificial heat and when brought into a warm room from winter temperature will become active in the course of a few minutes and will, if given an opportunity, begin operations for continuing its normal summer activities.

PROCEDURE OF BREEDING AND REARING.

In order to work out such a problem it was necessary to secure large numbers of the specimens in each of the stages in which growth and development occur. To accomplish this the adult beetles were collected, as needed, from dead pine limbs in the field, placed on freshly cut green pine in breeding jars and kept at a constant temperature of approximately eighty degrees Fahrenheit. This was accomplished by the use of a large pasteboard box in which was placed an electric bulb, of sufficient voltage, to keep the temperature within at about eighty degrees Fahrenheit, thus serving as an incubator in which the breeding jars were kept at all times. Moist sand was placed in the jars and the bottom ends of the pine sticks were imbedded in the sand and the upper ends were coated with parafin. This method of handling the breeding material conserved the moisture long enough, under the high temperature, to allow the broods to develop successfully.

It was possible to obtain some larvæ, pupæ and adults in the field when the work was begun in September but as winter advanced it became more and more difficult to find them in all stages, and finally the pupæ became so scarce that it was impossible to get enough with which to carry on the work. Although specimens winter over as adults and a few as larvæ, it would seem that almost none actually pass the winter as pupæ.

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*Felt, E. P. 1906. "Insects Affecting Park and Woodland Trees," Plate 68, Fig. 4; Plate 69, Fig. 1.

†Blackman, M. W. 1915. "Observations on the Life History and Habits of Pityogenes hopkinsi Swaine." Tech. Pub. No. 2, N. Y. State College of Forestry.

Adult beetles were collected every week and placed in new breeding jars so that a continuous supply of specimens in all stages were available simply by stripping the bark from the infested pine limbs and collecting the desired specimens.

As this species usually breeds only in the smooth bark of pine it was necessary to select pine limbs from one-half to two inches in diameter. It was possible to get larger sized limbs having smooth bark but they were not so easily handled in the breeding jars.

There are five larval instars; by that is meant five definite castings of the skin preceded by five short periods of growth. It was possible to place the larval specimens in their respective instars by the use of a table constructed by Doctor M. W. Blackman* in which it was shown that the width of the head is fairly definite for each instar. In part it is:

Instar	*Width of Head, mm.*
1	.300–.315
2	.345–.370
3	.412–.450
4	.475–.500
5	.520–.550

It then became a simple matter of measuring the width of the head of each of the larvæ, and placing them in their respective instars. A micrometer eye piece and compound microscope were used in making these measurements.

In order to secure pupæ of known ages large full grown larvæ were put into separate Stender dishes and examined daily for newly transformed pupæ. The selected specimens were larvæ from the fifth instar whose thoracic regions were swollen and enlarged and whose color was white due to cessation of feeding, thus presaging an immediate change to the pupal stage. Whenever new pupæ were found, they were also placed in other Stender dishes and examined daily until they reached the desired age. By this method it was found that the pupæ of this species, if kept under ideal conditions of moisture and at a temperature of about eighty degrees Fahrenheit, will transform to adults on the sixth day. Specimens of pupæ ranging in age from one to six days were secured in this manner and some were permitted to become callow adults to furnish specimens for study of the fully developed proventriculus as found in the adult beetle.

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*Blackman, M. W. 1915. Technical publication No. 2 of the New York State College of Forestry, page 39.

Technique of Preparing Microscopic Sections.

The method of handling specimens so delicate furnished considerable of a problem in itself and only after much experimentation with fixatives, stains, and imbedding materials was a satisfactory method worked out. The following is the method of killing, fixing and hardening, clearing, embedding, and staining, which gave the most satisfactory results with the specimens used. For suggestions regarding the histo-logic technique Lee's Vade-Mecum proved the most valuable reference.

Specimens were taken directly from their burrows and placed in Gilson's mixture which consists of:

Nitric acid, 46 per cent. strength	15 c. c.
Glacial acetic acid	4 c. c.
Corrosive sublimate	20 grms.
60 per cent. alcohol	100 c. c.
Distilled water	880 c. c.

This afforded a reliable and delicate fixation and left the tissue in a better condition than any of the other fixatives tried. Specimens remained in this fixative for twenty-four hours, after which they were removed and washed in water followed by a fifty percent alcohol solution and then run in the ordinary manner through the higher alcohols to ninety-five percent alcohol containing a few drops of iodine to remove the corrosive sublimate. Next they were put into a mixture of alcohol and ether fifty per cent each. From here they were placed into a two percent solution of celloidin, which was made by dissolving two grams of parloidin in a mixture of 49 c. c. of alcohol and the same of ether. After twenty-four hours the specimens were put for a similar period of time into a four per cent solution of celloidin and then removed and placed for five minutes in chloroform from which they were transferred to melted paraffin at 55 m.p. for five minutes and then imbedded in a small paraffin block by the drop method. The position of the specimens was indicated in the block of paraffin and the blocks were trimmed, mounted, and cut in series by the use of a rotary microtome. The specimens were cut five micramillimeters and seven and one-half micramillimeters thick—thinner sections of this material being impossible to secure with the mixed paraffin-celloidin method because of the difference in firmness of the two imbedding materials used. The knife in cutting thinner sections tended to compress the paraffin and to buckle the celloidin which usually broke the specimens up to a considerable degree. The sections, when cut of the proper thickness, came off the knife ribbon fashion and were fastened to slides with Meyer's egg albumen. It was found best to float them on water and warm the slides gently to flatten them on the glass. Xylol was used to dissolve the paraffin. A number of stains were tried but all of the sections used were stained in haemalum made as follows:

Haematoxylin	1 grm.
Water	1 liter
Iodate of sodium	2 grms.
Alum	50 grms.

They were counterstained in Congo red, made by dissolving it in ninety per cent alcohol. They were then cleared in xylol and mounted in Canada balsam for further study.

As it was necessary to study whole preparations of the proventriculus of adult beetles in order to get the relative position of some of its parts, a number of the beetles were broken apart at the juncture of the thorax and abdomen and the exposed proventriculus teased from the prothorax, and then fixed in alcohol, cleared in creosote, and mounted on glass slides for observation. Some whole preparations were studied while they were floating in the creosote. This was very useful as it allowed them to be turned about in any desired position.

Specimens were cut both in cross-section and longitudinally and completed preparations were classed as to the larval instar represented, the age of the pupæ in days, or as adult beetles, including several whole preparations of the latter stage. The sectioned and mounted specimens were saved to be used in working out the development of the proventriculus, and drawings of the various stages were made to aid in clarifying the descriptions given herein.

OBSERVATIONS.

LARVÆ OF THE FIRST INSTAR.

The proventriculus of the newly hatched larvæ shows, in cross section, indications of an outer layer of muscles, most of which appear, in relation to the proventriculus, to be circular muscles. Some, however, appear to be cut in cross-section, so are no doubt longitudinal muscles. This band of muscles is but a few cells in thickness and in some cases is not clearly distinguishable for the entire distance around the proventriculus. These muscles are more or less intermingled and cannot be differentiated into definite circular and longitudinal bands as are found in the higher animals and such as occur in the adult of this species.

Just within the muscular band is found a basement membrane which appears as a distinct line separating the muscular layer from the epitheial cells described in the following paragraph.

Next in order is a row or layer of simple columnar epithelial cells with their nuclei located near their basal ends, adjacent to the basement membrane. The nuclei stain blue with haemalum and are easily distinguished from the other parts of the cells. The basal ends of these cells contain the nucleus in which the chromatin network appears as dark blue thread-like structures. The cytoplasm, outside the nucleus, is finely granulated toward the proximal end, that is, next to the basement membrane, while towards its distal end it has more of a recticular structure. Covering the distal ends of the cells and lining the lumen is a relatively thin layer of chitinous substance which comes into direct contact with the food taken into the body. This chitinous layer entirely surrounds the lumen or central opening of the proventriculus.

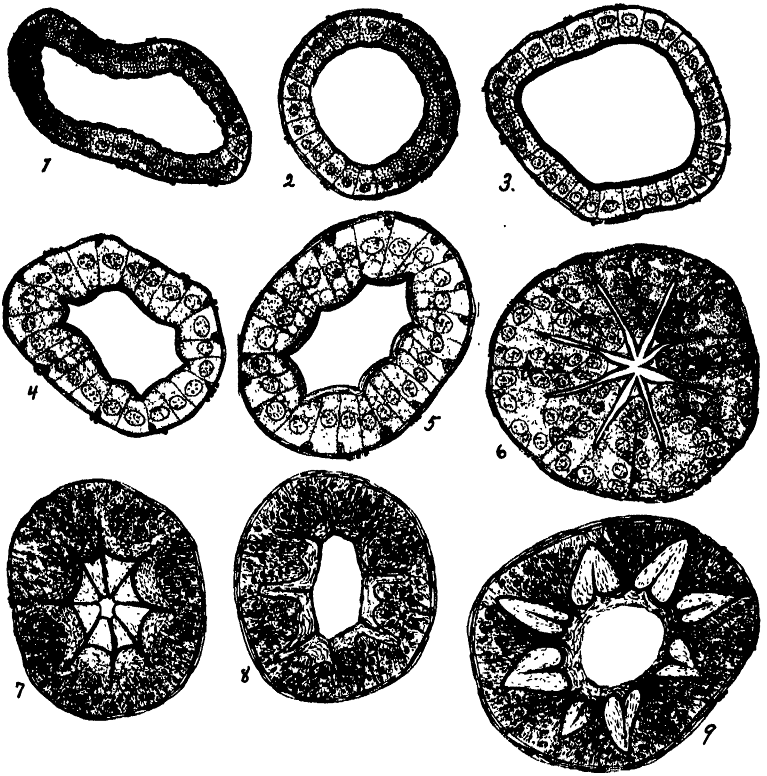
The parts then of the proventriculus of a very young larva are four in number, from the outside toward the lumen they are: the muscular layer, the basement membrane (not seen in cross-section except as a definite line separating muscle and epithelium), a layer of simple columnar epithelial cells, and an inner chitinous layer which is a secretion of the epithelial cells. These parts are shown in Figure 1.

LARVAE OF THE SECOND INSTAR.

This stage shows conditions very similar to those found in the first stage larvæ except that the circular-longitudinal muscular layer is somewhat more prominent forming a more nearly complete band, and the chitinous membrane given off or formed at the internal extremities of the epithelial cells is somewhat wider than is found in any of the larvæ of the first stage. Figure 2.

LARVÆ OF THE THIRD INSTAR.

This stage does not differ greatly from the two preceding stages except that the chitinous layer at the inner end of the epithelial cells is more in evidence and has become somewhat thicker than that found in the preceding stage. The simple columnar epithelial cells appear somewhat shortened in length and are more nearly cuboidal (square as



PROVENTRICULUS.

1. *Pityogenes hopkinsi* Sw., cross-section of larva of first instar X266, showing outer incomplete muscular layer, basement membrane, a layer of simple columnar epithelial cells, and an inner chitinous layer.
2. *Pityogenes hopkinsi* Sw., cross-section of larva of second instar X266, showing conditions similar to Figure 1.
3. *Pityogenes hopkinsi* Sw., cross-section of larva of third instar X266, showing conditions similar to those found in Figures 1 and 2.
4. *Pityogenes hopkinsi* Sw., cross-section of larva of fourth instar X266, showing addition of replacement cells at the base of the epithelial cells, and first indications of division in the epithelial layer.
5. *Pityogenes hopkinsi* Sw., cross-section of larva of fifth instar X266, showing increase in number of replacement cells, and division of epithelial layer into eight distinct corrugations.
6. *Pityogenes hopkinsi* Sw., cross-section of newly transformed pupa X266, showing increase in both number and bulk of epithelial cells, and infoldings in basement membrane.
7. *Pityogenes hopkinsi* Sw., cross-section of pupa one day old X266, showing reduction in size of epithelial layer, and sloughing off of the semifluid chitinous secretion nearly filling the lumen.
8. *Pityogenes hopkinsi* Sw., cross-section of anterior region of proventriculus of pupa three days old X266, showing divisions in epithelium at apices of corrugations.
9. *Pityogenes hopkinsi* Sw., cross-section of the posterior region of proventriculus of pupa three days old X266, showing active secretion and pouring out of cell contents into lumen.

seen in cross-section) than those of the second stage. Up to this time there has been no noticeable increase in the number of cells making up the epithelial layer, but due probably to expansion the proventriculus appears somewhat enlarged and this naturally reduces the length at the same time increasing the width of the cells present. Illustrated in Figure 3.

LARVÆ OF THE FOURTH INSTAR.

In this stage there is a still further step in the thickening of the chitinous layer. The most apparent difference found here, however, is the addition of a few small cells in between the bases of the columnar epithelial cells. These new cells are very small and are probably formed to take the place of the earlier cells which may be worn out or lost in growth and development and to aid in the great increase in the number of epithelial cells which occurs later. These cells are called replacement cells.

In the distal ends of the epithelial cells the reticulum appears very much coarser than in any of the preceding stages and it is a little more transparent. These small globules thus indicated are probably secretions in the formative stage which are to be used in the later development of the proventriculus.

In this stage the epithelial and chitinous layers, as seen in cross-section, are not the regular circular bands found in the preceding stages but both layers are more or less folded or corrugated thus producing the appearance shown in Figure 4. There is an occasional deep fold which reaches part way through the layer of epithelial cells toward the circular muscular layer. These folds occur at irregular intervals of three to five cells. The deepest reach one-fourth of the way down the cells toward the basal ends. These deeper and therefore more apparent divisions probably indicate a group formation of cells for a definite purpose, the significance of which will be seen later.

LARVÆ OF THE FIFTH INSTAR.

A very radical change occurs during the late fourth and fifth instar. It is during these stages that the insect undergoes probably its greatest amount of development while it is still taking food. It is then that it eats great quantities of food in preparation for its pupal existence. It builds up a surplus of tissues which prepares it for the very fundamental changes which take place during the pupal period. As the taking of food into the body of the pupa is a physical impossibility, it must depend on that which has been stored up previously.

The replacement cells are more numerous in the fifth larval stage than they were in the fourth instar. They still occupy their characteristic position between the bases of the cells as seen in cross-section.

In the fifth instar the deeper corrugations which first appeared in the fourth stage are more regular in arrangement and the epithelial layer is now separated into eight definite folds and elevations making, in cross-section, eight groups of cells which contain on their outer surface the large globules of secretion which later go to make up the newly developing parts.

The chitinous layer appears to be approximately the same width as that of the preceding stage. The muscular band shows no perceptible change in this stage of the development. An illustration of the parts as described under the fifth larval instar may be found in Figure 5.

EARLY PUPAL STAGE.

It perhaps may be well to mention here that conditions as described for this stage are sometimes, though rarely, found in the late fifth larval instar. There is an occasional overlapping of one stage into the next, and this is equally true of all of the other stages, for, like variations in the age of maturity of man, we find a difference according to individuals. However, a great many specimens were studied and the illustrations were taken from specimens which showed the most typical conditions.

In the early pupal period there appears a markedly different arrangement of the muscular layer, epithelial cells, and chitinous band, but their general relations to each other are similar. The cells which become grouped into eight longitudinal ridges or corrugations in the last larval instar have been further separated from each other. The replacement cells have proliferated to such an extent as now to produce a true stratified columnar epithelium, only the distal cells being of the columnar variety while the others are crowded between this outer layer and the basement membrane forming a mass of cells in no definite layers.

As shown in Figure 6., there has been a folding-in of the original epithelial layer. The bases of the columnar cells have torn away from the basement membrane and in so doing have retained parts of the membrane which appears in cross-sections of this stage as a definite line extending in as an axis of each corrugation. This is evident in very few of the later stages and is probably obscured by the dense crowding of the cells which are at this stage producing a great amount of formative secretion which is used, in the later stages, for the development of parts of the proventriculus. At the distal ends of the corrugations there appears to be a flaking-off of the chitinous layer into a flocculent or semifluid substance nearly filling the remaining lumen. The epithelium at its more distal portions has shrunken slightly away from the chitinous layer.

The outer muscular layer having no additional function beyond that of the preceding stage is of the same size and condition as previously noted. The changes which have taken place from the preceding stage to the one just described are shown in Figure 6.

PUPÆ ONE AND TWO DAYS OLD.

A rapid change takes place in the growth of organs in insects from one day to the next. In this stage there is a sloughing off of the secretion from the distal ends of the columnar cells of the epithelial layer, which are the only exposed cells. This, as it comes off, appears as a very broad band of chitinous material in a semi-fluid condition. The outline of the lumen remains the same as in the newly transformed pupæ but the groups of cells themselves occupy considerably less space than before. The cells are reduced in size by the discharge of their contained secretion, and the space thus gained is filled by this secretion.

The cells in the epithelial layer are more numerous—the additional ones having arisen from the cell division of the earlier replacement cells. In this stage the replacement cells cannot be distinguished from the original epithelial cells as they are diffused throughout the epithelium and are of approximately the same size as the reduced epithelial cells. The muscular layer shows no new development.

The preparation of the two day old pupæ are so similar to those of the one-day old pupæ that no illustrations seemed necessary or advisable and as development had apparently proceeded but very little, no description need be given. Figure 7 illustrates the condition as found in one and two day old pupæ.

PUPÆ THREE DAYS OLD.

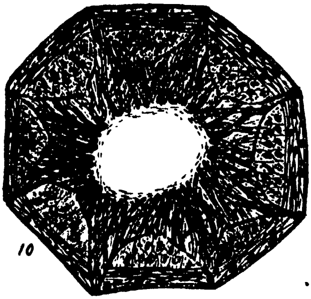
Up to this stage the development of the proventriculus has been uniform throughout its length but now there appears a difference in the anterior and posterior regions. The condition found in the forepart of the proventriculus, Figure 8, is relatively simple but the structure becomes more complicated in the posterior region as is shown in Figure 9.

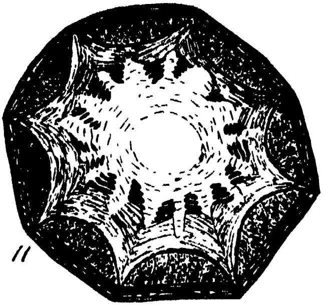
A cross-section in the anterior region of the proventriculus of a three day old pupa is very similar to conditions found in the one and two day old pupæ except that there is an additional grooving of the distal end of each of the eight distinct groups of cells. This partial division takes place in the epithelium and longitudinally marks off the corrugation into two nearly equal parts, which seems to indicate here the beginning of the formation of something further. The wide band of membraneous chitin persists but the distal portion appears to have shrunken away, leaving a larger central opening or lumen. The condition of the epithelium is similar to that described for pupal stages one and two, being made up of many cells forming a stratified columnar epithelial layer. The circular muscular layer shows no additional changes.

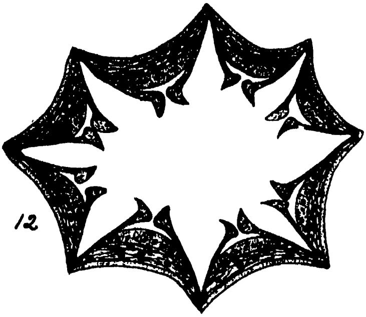
A section taken from the posterior region of the proventriculus of a three day old pupæ shows a remarkable difference from a section of the anterior region of the same specimen. It also differs considerably from sections through the posterior regions of younger stages of pupæ. It is plain in this stage that there has been a decidedly active secretion from the cells at the apices of the corrugations. This is accomplished by the pouring out of a large amount of the formative secretion already described as occuring within the cells. It passes out in the form of a stringy semifluid substance. The cells having given up considerable of their contents, are much reduced in size and the material secreted by them occupies all of the resulting space except a central cavity or lumen about equal in size to that found in the anterior region of the proventriculus of the same age pupæ. Most of the reduced columnar epithelial cells are arranged in rows just proximal to the viscid or semifluid chitinous secretions, while the other epithelial cells which are also much reduced in size and are of irregular shapes make up the remaining epithelial layer with apparently no definite arrangement.

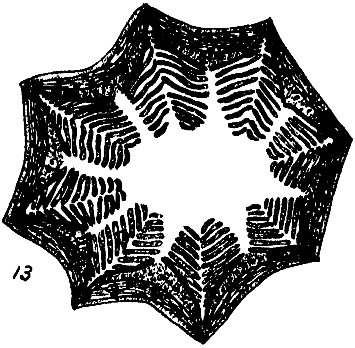
The outer muscular layer is of about the same thickness as found in the two day old pupæ, but has increased in size to conform to the increase in the size of the proventriculus.

In this stage the first extremely large, increase in the size of the proventriculus takes place and the area of a cross-section from a three day old pupa is more than twice that from either a one or a two-day old pupa—the diameter of such a cross-section being about one third greater than that of the preceding stage.









10. *Pityogenes hopkinsi* Sw., cross-section of posterior region of proventriculus of pupa four days old ×266, showing reduction in number and bulk of epithelial cells, strands of semifluid chitinous secretion, the much enlarged muscular layer, and the chitinous layer extending out into the muscular layer.
11. *Pityogenes hopkinsi* Sw., cross-section through posterior region of proventriculus of pupa five days old × 266, showing semifluid secretion near epithelial layer, and hardened portions of tips of forming plates more distal to it.
12. *Pityogenes hopkinsi* Sw., cross-section of anterior region of proventriculus of adult × 266, showing well-formed cutting teeth, reduced epithelium, a wide circular muscular layer, and an outer narrower layer of longitudinal muscles.
13. *Pityogenes hopkinsi* Sw., cross-section of posterior region of proventriculus of adult ×266, showing the edges of well-formed plates.

Outline drawings of Figures 1–13 inclusive and Figure 15, were made with a cameralucidia set at 70, using a ×6 ocular and a ×44 objective. Details were made under a ×95 oil of immersion lens with a ×10 ocular. The magnification was figured with a stage micrometer.

PUPÆ FOUR DAYS OLD.

This stage presents a still further complicated formation of new parts and shows a radical change from the three day old pupæ.

In the anterior portion of the proventriculus the change consists in the formation of teeth at the apices of the corrugations where the grooving occurred. The reason for the subdivision of each epithelial thickening is now apparent as from each of the subdivisions is now secreted a row of chitinous teeth. From each subdivision projections of the chitin appear which are plainly teeth in the process of formation. Their proximal portions are capable of taking some stain yet, but the distal edge and tips are more firm and show clearly the yellowish coloration characteristic of hardened chitin. As shown in cross-section, two large teeth in the formative stage are evident at the apex of each of the eight groups of cells.

In the posterior region the epithelial cells have been further reduced, as they also have in the anterior region, and a narrow band of more definite chitin is plainly seen in their distal surfaces and sides. The originally continuous layer of epithelium is now separated as each fold between the eight corrugations is lined by chitinous secretions which extend through the epithelium clear down into the muscular layer. This is due no doubt to the increase in size of the chitinous structure within the proventriculus which causes them to extend out beyond their former limits. The semi-fluid which was poured out from the epithelial cells in the preceding stage of the three day old pupæ is now arranged more definitely into strands interwoven and crossed. These structures appear to be arranging themselves into rake-like teeth and plate-like brushes.

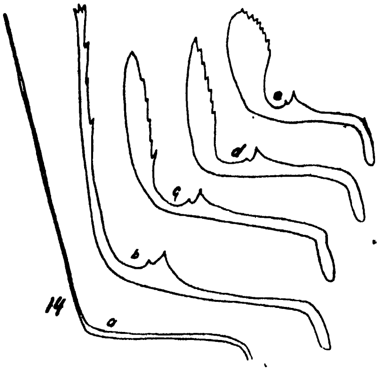
The chitinous layer is open at the point where the excessive secreting activity occurred in the three day old pupæ, that is at the apices of the corrugations. At the tips of the forming strands there appears a quantity of the unformed still semifluid chitinous material as in the preceding stages. The epithelial layer is very much reduced by this time.

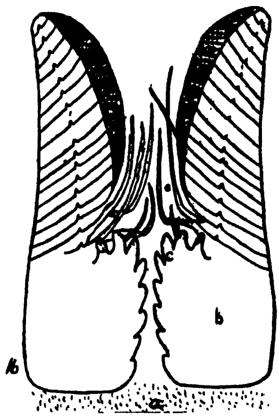
The circular muscular layer has become much thickened but longitudinal muscles are still very little in evidence. The increase in the size of the muscular layer is probably due to the necessity of additional muscles properly to operate the forming teeth, plates, and brushes. The significance of this will appear later. A cross-section through the forming plates, rakers, and brushes, is shown in Figure 10.

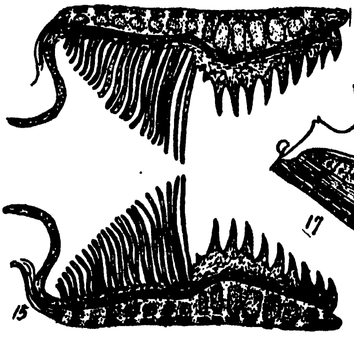
PUPÆ FIVE DAYS OLD.

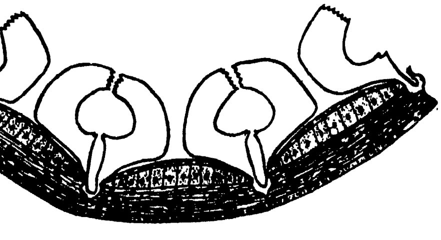
In the five day old pupæ the formation of parts of the plate-like structures from the secreted semifluid chitin is very plainly seen as shown in Figure 11. They are arranged in slanting rows and in cross-section they appear as a number of loose plates located well out in the lumen. Apparently they have risen from a portion of the secreted substance poured out into the lumen by the epithelial cells. They thus originate directly opposite the eight primary corrugations. As only the well defined edges of the plates can be found at the distal portions of the secreted substance, it may be properly assumed that the more distal parts of the plates are the first to harden into distinct chitinous structures. The more distal parts of the plates which are the first formed and are therefore firm and hard show very plainly, while the more newly formed portions which are still in the viscid state are not so apparent. These appear as a more or less flocculent material between the well defined edges and the epithelial tissue. There is also a general sloughing off of unformed chitinous material which appears as a flocculent formation and which only partially fills the lumen.

The chitinous layer next to the epithelial cells stains more densely than the less recently secreted portion distal to it and is probably in a









14. *Pityogenes hopkinsi* Sw., parts of proventriculus of adult greatly enlarged. (a) Straining bristle, (b) obstructing bristle, (c), (d), and (e), plate-like brushes.

15. *Pityogenes hopkinsi* Sw., longitudinal section of proventriculus of adult ×266. Anterior region is toward the right. Showing the arrangement of the various structures as seen in section. Note the wide band of circular muscles and the narrower band of longitudinal muscles.

16. *Pityogenes hopkinsi* Sw., diagramatic drawing of radial segment taken from proventriculus of adult greatly enlarged, showing relation of parts.

17. *Pityogenes hopkinsi* Sw., diagramatic drawing of portion of cross-section of proventriculus of adult greatly enlarged, showing method of attachment of plates into circular and longitudinal muscles.

semi-fluid condition. As in the preceding stage, the chitinous structure reaches, at the points of the folds, well into the muscular layer.

The circular muscular layer is considerably enlarged from earlier stages, but is similar to that found in pupæ four days of age.

ADULT STAGE.

On the sixth day the pupæ were found to transform to adults, sections of which showed clearly the final product of the elaborate process of development. This process includes the building up of many cells in preparation for the secretion of the complicated proventricular apparatus. Then followed the formation of these structures from the secretions of the epithelial cells. This was accomplished by a reduction in the epithelial elements as the cells were used up in the production of a relatively great amount of chitinous material in the course of a few days. Also coincident with these changes a great elaboration of the muscular layer takes place. This is a very essential part of the proventriculus as this organ is composed of sloping teeth, grinding plates, and straining brushes, and its equipment with strong muscles is very necessary for the performance of its functions.

A cross-section of the anterior region conforms in general outline to a similar section of the pupal stages already described. It consists of eight divisions of epithelial cells, separated by eight grooves extending to the muscular band, which at this stage is as large as the fifth pupal stage. In longitudinal section, there appears a narrow outer band of longitudinal muscles and an inner much wider, band of circular muscles. Figure 15. This formation of two definite layers is probably brought about by a proliferation and rearrangement in the original muscle cells. Within the inner muscular layer, the epithelial layer is represented by a few remaining epithelial cells. In some cases they are almost completely absent. Just within this layer is a very distinct chitinous plate having at the apex of each corrugation a pair of heavy sharp chitinous projections which point inward and backward. In cross-section Figure 12., they form a very formidable looking set of teeth.

The posterior portion of the proventriculus of the adult as seen in cross-section presents in outline form the same aspect as seen in the anterior region just described. The muscular layer is similar in size and structure, being divided into an outer longitudinal and an inner circular layer. As seen in cross-section this is not as evident as found in the anterior region, but when cut longitudinally the two muscular layers are very apparent. (Figure 15).

The chitinous layer separating the epithelial layer from the chewing plates is very evidently in the same relative position as found in the anterior region. Well formed plates such as those beginning to form in the fifth pupal stage are shown in cross-section of the adult beetle. These plates arise from an intermedian line between the apices of the corrugations.

The proventriculus of the adult *Pityogenes hopkinsi* is a very complicated structure. It is barrel-shaped when seen in whole preparations. It is radially symetrical being made up of eight sections which are som divided that each section is bilaterally symmetrical.

It seems advisable to begin at the anterior end of one of the halves of the eight bilaterally symmetrical sections and describe in detail the parts in the order in which they occur; that is, the parts which, when in their normal position, would be met in passing from anterior to posterior. It will be necessary to describe but one-half of this section as they are divided longitudinally so that they are bilaterally symmetrical.

From the anterior to the posterior are found: first the hair-like bristles on the crop. (The crop is a sac-like structure which is lined with chitin, as four days boiling in potassium hydroxide failed to dissolve it). On its inner side are found a great many tiny hair-like bristles whose function is uncertain. Next in order is the first part of the true proventriculus. Figure 16 b. It is a large chewing plate the median edge of which is lined with a row of cutting teeth. These teeth are quite heavy and coarse near the front and become larger and coarser toward the rear of the plate. They all slope backward. Posteriorly these teeth are found also extending circumferentially part way toward the intermedian line as shown in Figure 16 c. The side of the chewing plate divides near the intermedian line forming chitinous projections which pass out through the surrounding plate of chitin and fasten in the circular and longitudinal band of muscles.

At the rear of the large chewing plates arises a set of fine bristles. These are of varying length and are almost hair-like. They are simple in structure and possess no additional spines or barbs. Figure 14 a.

Next in order is found a set of obstructing bristles. These bristles are long, usually forked at the distal ends, and bear spurs and barbs along their sides (the side toward the lumen). Near the base of each rake-like bristle the shaft is widened to form a large flat plate-like spine armed with two barbs. This, when placed side by side with its neighboring plate, forms a row of sloping teeth which is inclined toward the rear of the proventriculus. The basal end of the obstructing bristle passes through the chitinous plate which lies next to the epithelium of the proventriculus, and attaches in the circular and longitudinal muscular layer forming the outer layer. These are illustrated in Figure 14 b.

Posterior to the obstructing bristles just described there is a series of broader plate-like or leaf-like structures the edges of which are fringed with spines giving them a bristle-like appearance. These structures bear near their basal ends the same type of flattened sloping teeth as described for .the obstructing bristles. The mode of attachment is also the same as is found in the preceding case. Distal to the basal section, however, the two structures are very different. The more posterior structure distally forms a plate instead of a bristle and the distal edge of this plate bears more spines than does the rake-like obstructing bristle. At the point where the plates and the bristles meet the former are but one-half the length of the latter. These brush-like plates, however, generally become shorter and still more brush-like as they are followed toward the posterior. These are illustrated in Figure 14 c, d, e, but there are types which intergrade between these. The plates are attached to the muscular layers in the same manner as the plates and bristles which have already been described. They also bear the sloping teeth near their ends. These sloping teeth which occur on all the brushes, bristles, and plates, at the same relative position, form a complete row. When the plates are in position, this row extends longitudinally the length of the proventriculus, posterior to the large chewing plates.

GENERAL POSITION AND RELATION TO BODY.

It is interesting to note the structure and position of each of the parts described as some indication to their purpose may be found by such a study.

The crop is a bag-like structure anterior to the proventriculus which serves to hold food particles taken into the body. While the food is in the crop, it undergoes a certain amount of maceration and preliminary digestion before it is passed on to the proventriculus. The presence of a crop allows the insect to store a considerable quantity of food which later passes on through the cutting and grinding proventriculus as this is able to take care of it.

The chewing plates with the cutting teeth on their median margins are attached to the muscular layers by chitinous projections which pass through the surrounding chitinous layer to the muscles. Contraction of the circular muscles drives the entire plate inward toward the lumen. A similar action of all of the plates at the same time considerably reduces the size of the lumen and brings the teeth in contact with the contents of the proventriculus. This results in the further comminution of the woody particles already chewed up by the mandibles and macerated in the crop. Thus contraction of the circular muscles drives the teeth inward. When the muscles relax the elasticity of the chitinous plate causes them to assume their former position. The mere fact that the teeth slope backward tends to drive the food in the same direction. The contraction and relaxation of the outer band of longitudinal muscles from front to rear in coordination with the circular muscles, causes a peristalic wave to pass backward in the proventriculus and consequently causes the food to pass in the same direction. The teeth on the edge of each chewing plate meet a similar set of cutting teeth on the edge of the plate making up the other half of the section. Thus these teeth work in opposition to each other and the result is an effective chewing up of the contained woody material. Following the chewing plates which have cutting teeth are the hair-like bristles the function of which is probably the straining of food particles. They serve to keep the larger particles back where the teeth can cut them small enough to be of use to the rest of the organism and at the same time to allow the already finely divided particles to pass on posteriorly.

Next are the rake-like obstructing bristles which probably serve about the same purpose as the hair-like bristles, keeping the larger food particles from passing through without further cutting. These bristles may act as a sort of supporting rack for the hair-like strainers anterior to them and serve to hold them in position against any pressure which may be exerted by the food. The rake-like obstructing bristles are also attached outside in the muscular layer and are capable of considerable movement. Their teeth may serve to aid in further breaking up the food, acting on the smaller particles just as the cutting teeth acted upon the coarser ones.

Posterior to the obstructing brushes are the plate-like structures the edges of which are fringed with fine spines making them appear brush-like. The basal ends of these plates are fastened in exactly the same manner as the bristles just described in the preceding paragraph. The contraction of the muscles drives the sharp toothed edge of the plates inward and together, much as in the case of the large cutting teeth. The more anterior of these plates have teeth on them capable of considerable cutting while in the posterior region they are more brush-like. It is probable that some grinding of food material takes place in the more posterior region of the proventriculus where the plate-like brushes occur. The basal ends of these plates pass outward and fasten to the circular and the longitudinal layer of muscles so that without doubt there is movement at least in two planes.

CONCLUSION.

It has been demonstrated in this paper that during the first three larval instars there is little change in the proventriculus of *Pityogenes hopkinsi.* It consists of a layer of simple columnar epithelium the distal ends of which are covered by a thin layer of chitin. Occurring at the base of this epithelial layer is a basement membrane which separates the epithelium from an outer muscular layer. This layer is made up of intermingled circular and longitudinal muscles, the former being more in evidence.

It is in the fourth larval stage that the first actual indications of any new developments are found. In this stage the addition of a few replacement cells occurs and changes in the arrangement of the epithelium begin which later divide it into eight corrugations. This process is continued through the fifth larval stage and during the first pupal stage. The replacement cells divide and redivide, producing many cells which are arranged to form a typical stratified columnar epithelium, in place of the simple layer of the early larvæ. This stratified epithelium is not uniform in thickness but is arranged to form eight distinct thickenings or corrugations extending lengthwise of the proventriculus.

In the first few days of the pupal stage the epithelium of the proventriculus becomes very active, filling a considerable part of the lumen with its secretion which is later to be used in the formation of new parts. As this arises during the first three days of pupal life it appears as a flocculent mass—apparently of a viscous consistency—and fills a considerable portion of the lumen.

From this formless mass the complicated chitinous structures of the proventriculus are formed during the last few days of pupal life. As it hardens the secretion takes the form of teeth, bristles, and variously modified plates.

A study of the later pupal stages shows that these chitinous structures begin to harden and take form at the tip first, i. e. at the portion farthest from the epithelium and nearest the lumen. This is demonstrated by a difference in staining power—the soft newly secreted chitin taking the Congo-red stain readily while the hardened chitin is impervious to stains.

With the beginning of secretory activity there is a great change in the epithelium. The distal ends of the larger columnar cells are apparently ruptured and the semi-fluid chitin streams from them. The cells are not only reduced in size by this but many are entirely used up as there is not only a reduction in the bulk of the epithelium by the time the pupal stage is completed, but an actual reduction in the number of cells.

In about the fourth day of pupal life a decided increase in the muscular layer is noticeable. Previously this has been inconspicuous and apparently little changed from the conditions in larvæ of the first instar. But in the late pupæ this layer is not only immensly thickened but is reorganized so as to form a definite inner circular and an outer longitudinal layer.

The circular layer is not a continous band but is divided into eight segments corresponding to the eight corrugations of the epithelium and the eight radial parts of the chitinous apparatus. These segments attach to the bases of the chitinous structures which extend out through the epithelium at an interradius (i. e. at each depression separating the corrugations).

The six day old pupæ change to adults and the proventriculus becomes fully developed. The epithelium is so nearly reduced that it is difficult to locate it at some places. All parts of the proventriculus—chewing plates, cutting teeth, straining bristles, obstructing bristles, sloping teeth, and plate-like brushes—are fully formed. They all slope toward the rear, but the straining bristles and the obstructing bristles are more nearly perpendicular to the basal chitinous band than are any of the other parts.

SOME OBSERVATIONS ON THE LEAF-MINING FLEA-BEETLE DIBOLIA BOREALIS CHEVROLAT.

By HELEN REED.

The plantain flea-beetle was first described by Chevrolat in 1844 as *Dibolia borealis.* It was later described by Melsheimer in 1847 as *Dibolia aera*, which synonym occurs very frequently in early American entomological journals.

It has at various times attracted attention by its rather conspicuous depredations on our common plantain. Scudder (1878) quotes from a letter from Professor F. H. Storer of Jamaica Plain, Mass . . . . . . "In the latter part of May, 1876, it was next to impossible to discover a single leaf of plantain that was not completely riddled by beetles (Dibolia aera Melsh) ". Several thousands from all sorts of situations had passed through his hands and the only perfect ones he could find were from particularly cold, sunless places on the north side of buildings.

Horn (1889) says "This beetle is so well known as not to require special comment." Patch (1908) gives some notes on the life history and says of its occurrence "Every season the bronze green flea-beetle of the plantain is found feeding upon the leaves of this plant early in the season and again later in the summer." Nevertheless careful observations on the habits and life cycle have never apparently been recorded.

The species is very abundant on the Cornell University Campus at Ithaca, and it was there that the present study was made.*

Host Plants: Both larvæ and adults, appear to feed exclusively on broad leaved plantain (*Plantago major*). Feeding sears, frass, and mines have never been observed on the narrow leaved plantain, or any other common weed on the Campus at Cornell, where the preferred food is so abundant. However in the laboratory with no other food supply at hand, larvæ have mined the leaves of the narrow leaved species. This species has not adapted itself to the miner. It quickly blackens in the mined area, and later shrivels and dies.

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*The author wishes to express her appreciation to Dr. James G. Needham, under whose direction the work was carried on.

Leaves of the broad leaved species, if not inhabited by too many miners, do not suffer; the plant has accommodated itself beautifully to ordinary infestation. However if there are too many tenants, the leaf is often killed and in some cases even the entire plant. The latter condition is unnatural, for the adults ordinarily do not deposit enough eggs on any one plant to kill it.

A curious response of the plantain leaf to the presence of the eggs of the beetle was observed. About the fifth day after the eggs were deposited, a sort of "humping up" of the eggs was noticed. This elevation became more noticeable on the succeeding days. It was found that the plant was forming a tissue under the egg similar to that of a gall. The larvæ were unhampered by it, and after burrowing down through the excess tissue, formed their usual mine.

Methods of Rearing: To observe copulation and oviposition, mating pairs were captured in the field and confined to breeding jars for observation.

The mining activities of the larvæ, as well as data on the number of molts, were determined by transferring newly hatched larvæ to fresh uninfested leaves. These leaves were kept in water in a moist chamber. This proved perfectly satisfactory.

The larvæ, when ready to enter the ground, were placed in a small quantity of fine earth in a watch glass. During the prepupal and pupal periods the soil was kept moist and the watch glasses themselves were kept in moist chambers. Using this method, it was very easy to examine the inhabitant daily.

SUMMARY OF THE LIFE HISTORY.

Presumably these beetles spend the winter as adults—as do most of the Chrysomelidæ—particularly the tribe of flea beetles, although definite observations have not been made. Since they pupate very near the surface of the ground, and since the period of pupation is so short, it is very unlikely that the species could hibernate as pupæ.

Adults began to appear on the Campus at Ithaca about the third week in May. Pairs were captured in copulation as early as May 18th. Evidently copulation had previously occurred in some cases for newly laid eggs were found on May 17th. No unhatched eggs were found in the field after July 1st, and during the week previous the only ones found were in cold, sunless places. The oviposition period for the brood extends over a period of about six weeks, though individual hibernating adults do not live for so long a period.

The season of 1926 was unusually late in this vicinity; according to Weather Bureau reports two weeks later than ordinary years.

The duration of the egg stage varies from 8 to 10 days under most favorable conditions. The larval period varies greatly with weather conditions; under most favorable ones it extends over a period of about 14 days, during which time the larvæ molt twice. When full grown, they make a slit in the epidermis of the leaf, and make their way into the ground. Here they form an oval pupal cell, in which they spend from 5 to 9 days as prepupæ, and from 9 to 12 days as pupæ. The adults emerge from the ground fully colored and chitinized and begin to feed immediately. There appears to be but one generation a year since no mating occurs in the new brood.

In a breeding jar, in which conditions were kept as nearly like those of the open as possible, the complete life cycle took place in 45 days. The egg stage appears normally to cover a period of 10 days, larva 15 days, prepupa 8 days and pupa 12 days.

Hibernating adults, even in the coldest, most sunless situations, were all dead by the middle of July, at which time adults of the new generation had already appeared on the warmer southern exposure.

LENGTH OF DIFFERENT STAGES.

Under most favorable conditions out of doors as well as in the laboratory, eggs were hatched in 8 to 10 days. Temperature and moisture apparently have considerable effect upon the length of this stage. Both dryness and cold prolong the period. Certain eggs laid during very dry weather did not hatch.

The first molt takes place on the fourth or fifth day. The second molt takes place on the seventh or eighth day; the duration of this period is therefore about three days. The length of the third larval instar varies greatly under different conditions. The first larvæ hatched in the laboratory left the leaf to enter the ground at the end of fourteen days, during all of which time they fed actively. Later in the season certain larvæ, after two weeks of active feeding remained a week or ten days in a quiescent stage in the leaf. Records were kept of these particular larvæ and it was found that they required as long a prepupal period as larvæ, leaving the leaf at the end of the two weeks. Weather conditions again affect the length of the period.

The length of the prepupal period varies from 5 to 9 days, while 9 to 12 days are spent as a pupa.

DESCRIPTION OF DIFFERENT STAGES.

Egg: (Plate XXVII, Fig. 9)—Light golden brown; ovate and flattened somewhat on uppermost surface. Length about .67 mm.; greatest width .32 mm. Surface covered with minute indentations.

The eggs are commonly deposited upon the upper surface of the plantain leaf (*Plantago major*), although the writer in a few instances has observed eggs on the under surface of the leaf.

The female eats out a small area on the leaf leaving the lower epidermis and some of the spongy cells. She then circles about the opening until she is in a proper position to insert the egg into the depression, slightly larger than the egg itself; a single egg is inserted together with some excretory material. At first the entire mass is a pale amber color; in less than fifteen minutes the excrement hardens and darkens and forms a roof-like covering to which the egg adheres. The beetles were not at all hesitant about oviposition in the laboratory. When the larva is ready to emerge it leaves the shell and directly begins its characteristic habit of mining, without appearing on the surface of the leaf.

Larva: (Plate XXVII, Figs. 1 and 2)—The length of the mature larva varies from 5.75 to 6 mm.; the head capsule measures .5 mm. in width. The general body color is a deep yellow. The body and head are flattened dorso-ventrally; the thoracic and abdominal segments have distinct lateral processes or tubercules.

The head (Plate XXVII, Figs. 4 to 8) is deeply notched behing, wedge-shaped in front and projects back into the prothorax for about a third of its length. The mandibles are large, thin and flattened. The prominent maxillary palpi are three segmented. The antennæ are relatively small and three segmented. Ocelli are wanting. The head is very dark brown, nearly black; the dorsal and ventral prothoracic plates are somewhat lighter in color.

On both the meso and metathoracic segments are found a pair of lateral grayish kidney-shaped spots bearing setæ. The legs are well developed and composed of five segments. The distal segment bears a single claw and a pulvillus.

The abdomen is composed of ten segments, the 9th and 10th are much reduced. (Plate XXVII, Fig. 3). The 10th segment is readily seen only in a lateral view. A single median anal prop-leg is borne by the 10th abdominal segment. Abdominal setæ in more or less regular transverse rows are present on each segment, a double row dorsally, a single row ventrally. The whole body is covered with small grayish oval spots.

When the larva first hatches from the egg it is yellow. The color gradually changes to a creamy white, which color is retained until the last part of the third larval instar, when it gradually becomes a deep yellow. The head in the first and second instars is proportionately much larger in comparison with the size of the body. The head capsule of the first instar measures .25 mm., the second instar .38 mm.

In 1879 Comstock described the larva of *Dibolia aerea* (—*D. borealis*). It is possible he has described a different insect, since the larva studied in this investigation differed markedly from his characterization. The outstanding differences are shown by the following table:

	Comstock's Description.	*Larva Studied.*
1.	Length, 8 mm	Less than 6 mm.
2.	Color white (full grown)	Yellow.
3.	Second and third thoracic segments with transverse grayish spots	With lateral longitudinal grayish spots.
4.	Thoracic subdorsal spot	No subdorsal spot.
5.	Small round darker spots on second and third thoracic segments	None.
6.	Dorsal spots on seventh and eighth abdominal segments	None.
7.	Anal plate	None.

Prepupa: Ordinarily as soon as the larva is fully fed, it enters the ground to spend the prepupal and pupal periods. During this time it shrinks, becomes more deeply yellow and in the last two or three days becomes strongly arcuate and unable to move.

As the larva moves about on the ground preparatory to entering the soil, it is very careful to choose a spot in which the soil particles are fine and preferably a little moist. It pushes its way down through the soil for a distance slightly less than an inch, and there by the twisting and turning of the body, and by a secretion, probably from the salivary glands, forms an ovate cell.

Pupa: (Fig. 1). The prepupa molts to the pupa ordinarily on the 7th day, and the cast skin is found in the cell. The pupa itself lies ventral side uppermost. The length is 2.93 mm., the greatest width 1.84 mm. The color is pale yellow and the general appearance is typically Chrysomelid.

During the first half of the period the pupa is quite active; when disturbed, by flexing its abdomen can change its position considerably. About the 4th day the eyes begin to darken and thereafter, legs, mouthparts and true wings. The elytra do not darken during the pupal stadium. The adult emerges on the 8th or 9th day after the prepupal molt, fully formed, light in color, inactive and still in the ground. In a few hours the elytra, head and thorax darken and finally the under parts. The adult appears above the ground about 24 hours after emerging and begins feeding immediately.

Adult: (Fig. 1, Length, 3mm., Horn 1889). When the beetle first emerges from the pupal skin, it is as yellow in color as the pupa was. The legs and mouth parts are dark, the wings grayish, while the elytra and the under surfaces are pale yellow and slightly irridescent. Coloration takes place gradually; the upper parts become bronzy green in about twelve hours. Twelve more hours elapse before the under parts are fully colored. The beetle does not make its way above the ground until fully colored, although when disturbed it is able to move about and even leap characteristically.

The females appear to be slightly broader and the males more perfectly oval and seem to have a higher metallic lustre. However it is practically impossible to distinguish the sexes.

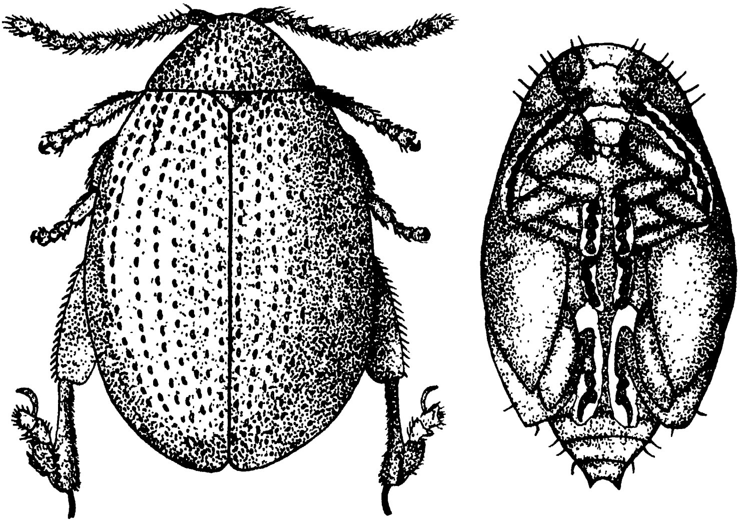

Figure 1. Adult and pupa of *Dibolia borealis*.

ACTIVITIES OF THE PLANTAIN FLEA-BEETLE.

Feeding habits of larva: As already stated, the larvæ live within a mine, which they enter directly from the egg. Here with the two epidermal layers as shelter they are surrounded by an abundant food supply. When first formed the mine is very shallow and hard to distinguish; but few cells of the palisade layer are eaten. After the first molt, the larva feeds more deeply, removing the palisade and most of the spongy layers. After the second molt the entire space between the two epidermal layers is consumed (Fig. 2-z).

The mine is linear in form, though the larva frequently turns about feeding as it does so, and thus forms blotches along the way. Quite commonly, the larva makes a mine, then retraces its course and makes a side branch to it. Usually the larva prefers not to cross a large vein in the leaf, instead will often follow the course of the vein for considerable distance, and finally form a branch in the other direction. The surface of the leaf is "humped up" by the larva in its quarters, quite a characteristic habit of this miner. Frass is deposited in a mid furrow in the mine. The edges of the mine appear to be "scalloped." (Fig. 2-x). This is due to the characteristic feeding habits. The larva holds its body stationary as it feeds, while the head is moved from side to side, until all the cells within reach have been devoured. Then the body is pushed forward and the whole process is repeated.

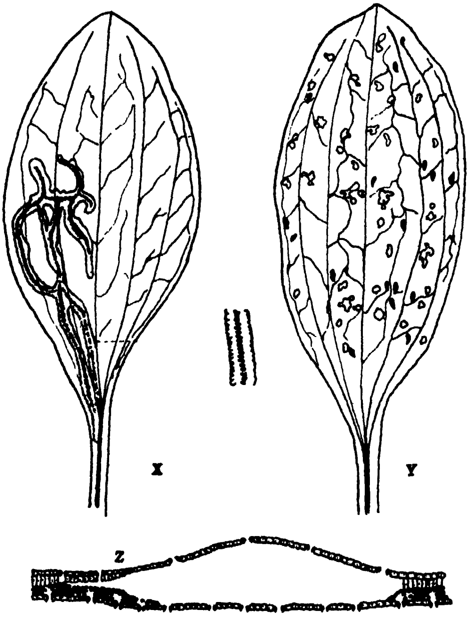

Figure 2. Infested leaves of *Plantago major*. X, Leaf showing mining operations of one larva; Y, Leaf showing eggs and feeding scars of adult; Z, Diagram of cross-section of a leaf showing depth of mine.

If the leaf becomes dried or too densely populated, the larva will leave, wander about on the surface of the leaf and eventually re-enter a new and fresher area or even a new leaf if close at hand. A slit greater than the width of the larva is made in the upper epidermis and the larva slips under it, feeding as it does so.

Newly hatched larvæ will re-enter and mine the leaves of the narrow leaved plantain, though they never apparently choose it under natural conditions.

There is but one tenant in the mine, although there may be as many as five, six or seven healthy miners on a single leaf, each following its own course, and each reaching maturity.

Feeding habit of the adult: Directly after the adults have emerged, they begin to feed actively removing practically all of the upper epidermal palisade and spongy cells of the broad leaved plantain. The areas eaten out are small, frequently as small as the areas where the eggs are to be laid (Fig. 2-y). After a number of beetles have been feeding on a leaf for several hours, as in a breeding cage, the leaf assumes a lace-like appearance, dotted with black spots of excrement.

Adults are frequently found feeding on the under surface of the leaf, in this case leaving only the upper epidermis.

On cold, cloudy or wet days during May and June, the adults are very inactive and are found at the bases of the petioles of the leaf where they are somewhat sheltered. On a cold, damp morning therefore adults were easily caught. On a warm, sunshiny day when the beetles are busily engaged in feeding on the blades of the leaves, the little creatures leap at the slightest stirring of the vegetation, and are as elusive as true fleas.

The larger open holes of the plantain leaves are the feeding scars of some other insect, for none of these beetles observed in the laboratory made a scar even approaching the size often seen, in which both the epidermal layers are eaten as well as the cells between.

Copulation: Males and females were frequently seen and caught in copulation. In a mating pair caught and kept in captivity copulation was twice observed. It is possible that mating occurred previous to their capture and at other times in the laboratory when not observed.

Number of eggs: The egg complement is not all deposited at one time; egg laying covers a considerable period. Under natural conditions the female lays but few eggs on a leaf. All the leaves of a plant in a breeding jar were literally covered by feeding scars and eggs from a single pair.

Natural enemies: Larvaæ in the field as well as in the laboratory are attacked by some kind of fungus. Apparently the conditions most favorable to their growth were present in Ithaca during late June and early July, for many larvæ were found dead in the mines from this infestation.

The larvæ of this beetle are unusually free from parasites. On one occasion however, two Hymenopterous larvæ were found in the mines on two different leaves.

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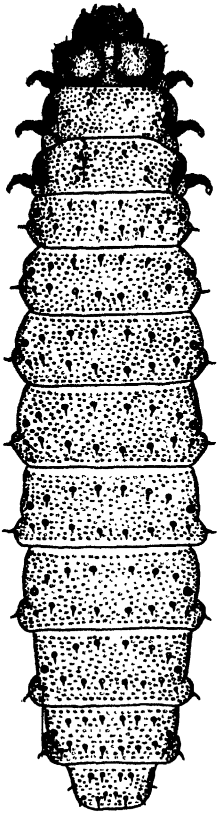
EXPLANATION OF PLATE XXVII.

Fig. 1. Grown larva of *Dibolia borealis*. Dorsal view.
Fig. 2. Grown larva of *Dibolia borealis*. Ventral view.
Fig. 3. Side view of larva showing 10th segment.
Fig. 4. Head. Dorsal view.
Fig. 5. Maxilla.
Fig. 6. Labrum.
Fig. 7. Mandible.
Fig. 8. Antenna.
Fig. 9. Egg, with excrementitious envelope.



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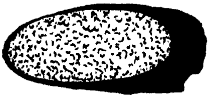

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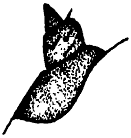

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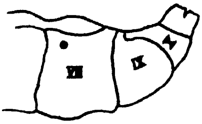

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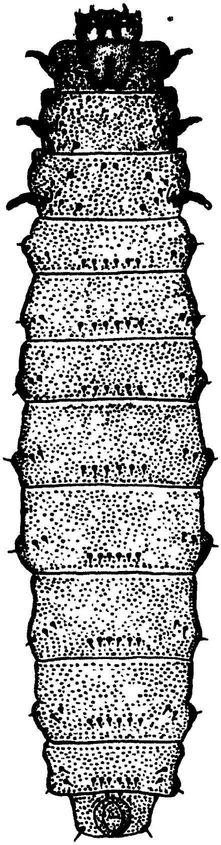

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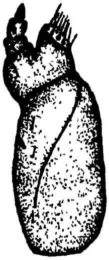

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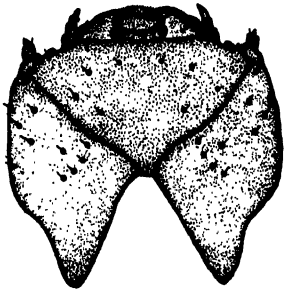

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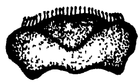

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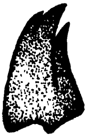

7

Helen Reed

FURTHER OBSERVATIONS ON THE OLFACTORY POWERS OF THE NECROPHORI.

C. E. Abbott.

In June, 1927, I published a paper giving the results of some experiments on the olfactory peculiarities of *Necrophorus americanus* and *Necrophorus orbicollis*. These results left one question only partially answered, and raised another of some importance. The first related to olfactory threshold; the second to the possible olfactory function of the palpi. During July of the past summer I had at my disposal the Zoology laboratories of the University of Wisconsin. The nearby woods yielded about fifty specimens of N. orbicollis. These furnished sufficient evidence for the conclusions given here.

OLFACTORY THRESHOLD.

The following tests were made with solutions of skatol in very pure distilled water. The dilutions were made with a burette, and were measured as grams per 100 c.c. of H_2O. The dilutions used were .00833, .00333, .0008, and .00024. Sheets of four-ply towelling measuring 4 x 4 inches were saturated with solutions and buried in the cage. In most cases a control, consisting of a similar pad wet with distilled water, was used. The results of experiments were considered positive if the test papers were unearthed, or if beetles were found beneath them. The tests were performed in the cage in which the beetles were kept; a wooden box 12 x 18 inches and about 12 inches deep. It was half filled with sand. The time factor, while not very constant, was usually about twelve hours.

The results of these experiments may be summarized as follows:

Experiment 1. A saturated solution of skatol was used. Of the sixteen beetles in the cage, fifteen went under the test paper.

Experiment 2. A .00833 solution was used with twenty-eight beetles. The results were entirely negative.

Experiment 3. A .00833 solution; and twenty-seven beetles were tested. Two were found under the test paper.

Experiment 4. A .0008 solution; and twenty-seven beetles were tested. No control was used. Twenty beetles were found under the test paper.

Experiment 5. A .0008 solution was used, and twenty-seven beetles were tested. The control paper was buried under a spot where some meat had been lying for several hours. The beetles unearthed both the test paper and the control in a single night, and chewed them very much. When supplied with meat, these beetles attacked it voraciously.

The four remaining experiments, employing .00024 skatol solutions, gave completely negative results.

THE PALPI.

These experiments were performed in a regular insect breeding cage such as is often used for caterpillars. It was about 18 inches high and 12 inches square, and was filled to a depth of two inches with sand. A piece of meat was fastened at the top of two alternately inclined planes. Of the twenty beetles in the cage, ten had amputated palpi, and were so marked that they could be easily distinguished from the normal insects.

The results were as follows:

On July 11th two normal beetles were feeding on the meat.

On July 12th two normal beetles and three without palpi were feeding.

On July 13th four normal beetles and five without palpi were feeding.

On July 14th two normal beetles were feeding.

The meat was then removed from the plane and suspended from the top of the cage so that it was a few inches above the sand. In this position even normal beetles would not respond to it, and so it was put at the top of a single inclined plane. On July 17th two beetles, one without palpi, were found on the meat. The following evening a single beetle with amputated palpi was feeding.

At this point general tests were discontinued, and a few beetles were tested with essential oils. Normal insects were used as controls. The method was to bring a bit of wood saturated with the test substance within a few millimeters of the beetle's head. If the insect did not move within sixty seconds the response was considered negative.

INDIVIDUAL	CONDITION	TEST SUBSTANCE	RESPONSE	REACTION TIME
I (tomentosus)	normal "	bergamot wintergreen	+ +	immediate 5 seconds
II (orbicollis)	no palpi " "	bergamot wintergreen	+ ?	10 seconds
III (orbicollis)	" " " "	bergamot wintergreen	+ +	immediate 10 seconds
IV (orbicollis)	" " " "	bergamot wintergreen	+ —	5 seconds
V (orbicollis)	normal "	bergamot wintergreen	— —	
VI (orbicollis)	no palpi " "	bergamot wintergreen	+ +	20 seconds 5 seconds
VII (orbicollis)	normal "	bergamot wintergreen	+ +	30 seconds 8 seconds
VIII (orbicollis)	no palpi " "	bergamot wintergreen	+ +	45 seconds 8 seconds

GENERAL CONSIDERATIONS.

It is strange that the results obtained relating to the olfactory threshold of the Necrophori differed so much from those obtained in the summer of 1926. The difference was in some way related to the behavior of the two groups of beetles. Those used in the recent experiments were always restless and hungry; it was impossible to satisfy them. Moreover, for some inexplicable reason, great numbers of them sometimes died over night. None of these phenomena were observed the summer before. They must be related to factors which are not yet well understood. The data obtained in the two cases do not invalidate each other, but it is evident that neither can be wholly accepted without further confirmation.

The results relating to the palpi were more gratifying. Vision can be eliminated as a factor in these experiments. Former tests have convinced me that the visual powers of the Necrophori are not particularly good. The very fact that the beetles are nocturnal, and work in almost absolute darkness, sufficiently demonstrates the importance of the olfactory sense.

After considering these reservations, it is quite certain that the palpi have very little, if anything, to do with olfaction. This enables me to state my position once more: I cannot understand how the olfactory organs of the Necrophori can be localized, and the only alternative conception is a general distribution over the surface of the body. In view of the evidence, the generalizations of von Frisch (1921) seem premature.

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THE DEVELOPMENT OF COCCOPHAGUS GOSSYPARIÆ GAHAN, A PARASITE OF THE EUROPEAN ELM SCALE.

Grace H. Griswold,
Cornell University.

While working on the biology of the European elm scale (*Gossyparia spuria* Modeer) during the spring of 1924 some males were found that appeared to be parasitized. This condition was first noticed while the male coccids were still in the second larval stage although their cocoons had already been formed. Upon dissecting some of the parasitized individuals each was found to contain a pale cream-white hymenopterous larva, apparently about ready to pupate. Their feces had been voided and lay about them in the form of flat black plates. In order to get an idea of the percentage of parasitism counts were made of a number of males. An examination of 163 coccids showed that 47 (28.83%) of them were parasitized. A few days later hymenopterous pupæ were dissected from some of the male coccids. Measurements of a number of these pupæ showed them to be about 1.2 mm. in length and 0.54 mm. in width. The general color of the pupa is black although the thorax and the abdomen are slightly lighter than the head and have a somewhat greenish tinge. On the ventor, the thorax and the abdomen are much lighter, the latter being a pale greenish-white but with a dark area at the caudal end. It was noticed that the pupa usually lies with its head at the posterior end of its host's body though some were found in a reverse position.

The first adult parasites emerged in vials on May 19th and they continued to emerge for nearly two weeks. Each had cut a neat round opening in the body of its host and a second opening in the host's cocoon. The exit hole was usually found to have been made near the center of the dorsum although in a few instances exit holes were found at one end of the coccid's body. Specimens of the chalcids were sent to Washington for determination and have lately been described by Gahan (1927: 24) as *Coccophagus gossypariæ.* Cooley (1898:63) reared a parasite from the European elm scale and sent specimens to Washington to have them identified. Dr. Howard found them to be a new species to which he gave the manuscript name of *Coccophagus gossypariæ.* No description, however, was published at that time. The parasites reared in the present study were compared by Gahan with the Cooley specimens and found to be the same. Gahan in his recent description of the species has retained the name given the insect by Dr. Howard in 1898.

At about the time that the parasites began emerging the mature female coccids had settled on the twigs and started their semi-cocoons. An effort was made to get the chalcids to oviposit in some of these individuals. Bits of twigs on which the scale insects had settled were put in small vials into which parasites were also inserted. The parasites showed great interest in the coccids, walking back and forth over them and tapping them with their antennæ. Later on, however, when the coccids were removed from the vials and dissected no eggs could be found.

In late June coccid females from five different elm trees were dissected for the presence of parasites. The total number of scale insects so examined was 316 and of these 94 (29.77%) were found to be parasitized. Some of the parasites were tiny larvæ, others more fully developed and still others had pupated. A full grown chalcid larva of the second generation is larger than one of the first generation, probably due to the greater amount of food supply afforded. It occupies a U-shaped position in the body of its host which by this time is nothing but a hollow shell.

When ready to pupate the larva gives off its excrement, straightens out and lies at one end of the host's body. The pupa may lie with its head at the cephalic end of its host or in a reverse position or it may lie slantwise. As in the case of the larvæ, the pupæ of the second generation are somewhat larger than are those of the first generation, but otherwise no difference was noted.

The first chalcid adults emerged in vials July 9th. In order to avoid any possibility of error, specimens were sent to Washington for determination. They proved, however, to be the same species as those which had begun to emerge from male coccids six weeks before.

It is evident, therefore, that there are at least two generations a year of this parasite. The first generation parasitizes the male scale insects before they have fully matured. The second generation, on the other hand, attacks the Gossyparia females. The adults of this second generation emerge at about the time that the eggs of the scale insect are hatching. At Ithaca *Gossyparia spuria* has only one generation a year and passes the winter in the second larval stage. The manner in which the parasite over winters is yet to be determined.

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